Instruments

THE MAGAZINE OF

Measurement and Control

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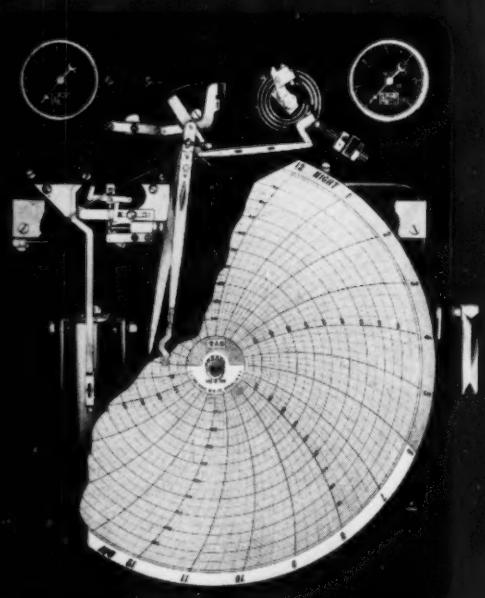

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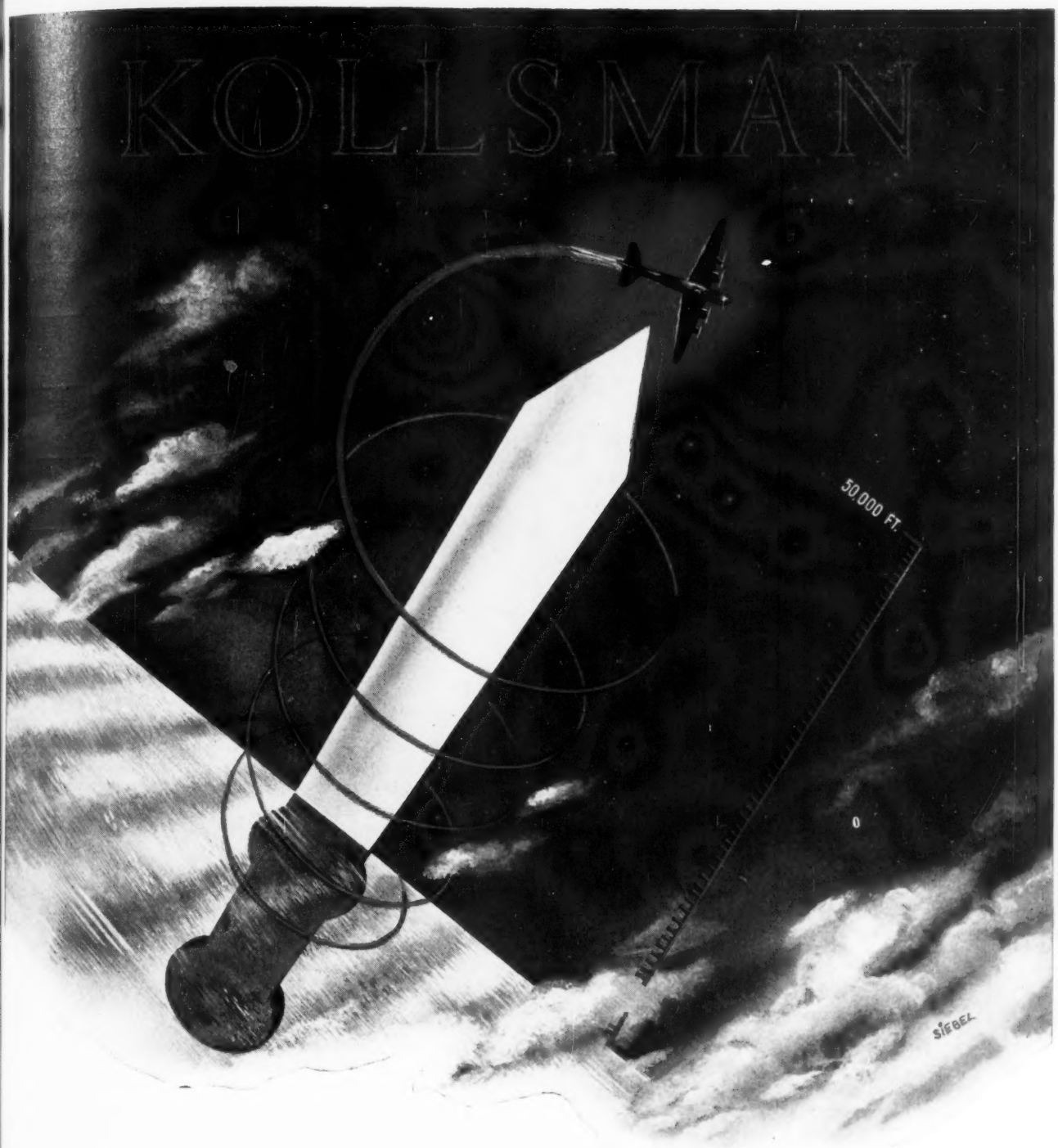

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Automaticity *Makes* Jobs

DESPITE the factual expositions of engineers, industrialists and economists who *know* the wealth-creating and wealth-distributing consequences of adopting cost-cutting devices, the anti-science, anti-machine, anti-progress agitation goes on and on.

It is becoming plainer that more than one selfish agitator is inflaming the rabble against labor-saving devices (and against private ownership thereof) in an attempt to become a dictator. Curious to know our enemies' tactics, we have listened to their broadcasts and read their printed manifestos, and find that no matter what panacea they lead up to, their common theme is the old hokum about a handful of plutocrats owning eight-tenths of all the means of production—from farm lands, cattle ranches, forest and mines to all the various processing and fabricating industries; nine-tenths of the means of transportation; and seven-tenths of the agencies of distribution. *Therefore* the plutocrats adopt labor-saving machines and methods to create hordes of unemployed who scramble for scarcer jobs. *Therefore:* (1) turn over the Federal Reserve to a few hundred slick politicians elected by popular vote, or (2) give half our national income to the aged; or (3) grab all privately-owned land; or (4) steal the factories and railroads and chain stores from their legitimate owners.

Throughout these fulminations runs the thread of resentment against technological progress: the would-be Hitlers claim that *because* we have emerged from the covered-wagon age it has become possible for a few plutocrats to own nearly everything and *therefore* we must kill, jail or otherwise dispose of the plutocrats, abolish our form of government . . . and give supreme power to Mr. X or Doctor Y or Father Z—who of course would somehow "distribute the wealth" . . . Of course! . . . Somehow!

What the would-be dictators conceal is that "purchasing power" is not absolute but relative. Automatic devices bring *down* the cost of cars and radios and gas and oil and electric energy and processed foods and good clothes and modern houses, thereby enormously widening the markets and creating millions of *new* jobs. These jobs are in "privately-owned" establishments. What of it? Under communism or fascism there would be even fewer overlords, exercising a far more despotic power without the possibility of tripartite governmental regulations.

For proof that automaticity *makes* jobs by making possible mass production, look at the automobile industry.

M. F. BEHAR

The above may sound familiar to old subscribers. It appeared on this page twice: in Dec. '35—in large type nearly filling the whole page—then again in July '37 by request of many subscribers. It is reprinted now because the enemies of labor-saving methods are preparing NOW to impede the growth of instrumentation. They are the same anti-American rabble-rousers under new organization names, disguising themselves as patriots. Don't underestimate their unholy zeal: they have already introduced anti-technology bills in Congress. Wake up!

Yes, wake up! Don't laugh me off as an old codger who imagines bolsheviks and fascists hiding under his bed. If you'd seen the evidence I saw, you'd agree with me (as did Federal authorities). What I'm fighting FOR is your future prosperity—hundreds of thousands of NEW jobs for instrument men in an EXPANDING post-war Industrial America. That's why I fight AGAINST your enemies in our midst. I can't do it alone. So act! Tell and write everybody, including your Senators and Congressmen, that labor-saving instruments are a PURE blessing, speeding the War Effort now and stimulating employment later.

Jewel Bearings Eased Up

WAR PRODUCTION BOARD

To the Editor of *Instruments*:

We are enclosing a copy of the amended M-50 Conservation Order. The following are some of the changes:

1. Paragraph (c), which specified the only permitted uses of jewel bearings, has been removed from the Order. Formerly, in order for the consumer to use any jewel bearings for any use other than the one defined in Paragraph (c), it was necessary to file an appeal asking for relief under the Order. The necessity for filing such appeals is eliminated. In this same connection, Paragraph (a) (13) which defined "Implements of War," one of the chief end uses, has been eliminated.

2. The definition of "jewel bearings" was changed by eliminating needles, stylii, cutters, nozzles, supports, tool bits, and dies. It will no longer be necessary for suppliers of these items to report their production nor for consumers to report their consumption of these products. Also, deliveries, processing, and use will not be restricted.

3. The definition of "consumer" has been changed so that a person who uses jewel bearings in the repair of watches or instruments will no longer be required to file any reports.

4. The restrictions on the delivery, processing, and use of substitute jewel bearings have been removed from the Order; therefore, substitutes will not be subject to allocation.

5. Consumers of jewel bearings or substitute bearings who use 10,000 or more per quarter will be required to file monthly reports; consumers who use between 500 and 10,000 per quarter will be required to file quarterly reports; consumers who use 500 or less per quarter will not be required to file any report on their consumption of jewel bearings or substitute bearings.

Allocations will continue to be made on a monthly basis, and it will still be necessary for the suppliers to procure authorization to make shipments. The War Production Board will continue to notify the consumer of the type and quantity of the allocation.

6. Paragraph (f) (3) has been changed to make it unnecessary for producers or suppliers to report their production and to request authorization for delivery of natural sapphire or natural ruby.

We would like to point out Paragraph (f) (4), "Specific Exemptions," which we had inserted in the Conservation Order. According to this paragraph, if circumstances show such uniformity of production or requirements as to indicate that the filing of reports is no longer necessary, we can authorize a supplier or consumer to discontinue filing reports without amending the Conservation Order.

Our Order as it now stands has been held up to other Divisions of the War Production Board as a good example of eliminating restrictions on industry. We would appreciate it very much if you could put something into *Instruments*, so that the general public would have authoritative information on jewel bearings.

CHARLES D. BURGESS,
Jewel Bearing Section
Miscellaneous Minerals Division
WPB Dept. 7525

ELECTRIC GAGING METHODS
for Strain, Movement, Pressure and Vibration

By HOWARD C. ROBERTS, University of Illinois

EDITOR'S PREFACE

FOR perhaps ten years the need of a book on electric gaging methods has been evident, becoming more evident with a growing awareness that electric "gaging" principles find use in many fields of measurement —and of automatic control. This need became critical recently as the number of practical but uncommercialized methods outgrew any engineer's ability to find them in his company's library—even in large technical libraries. Hundreds of titles afford no clues to the gaging-method disclosures within. Even most abstracts have in this respect a "hiding power" like that of black paint! A further complication is that new methods came out in more than twenty countries. There has been talk of creating a large literature-research committee—necessarily made up of specialists from ten or more societies. But the resulting bibliography would be indigestible—even in some cases a deterrent to possibly fruitful effort (the familiar "someone-beat-me-to-this-idea-and-no-doubt-he-has-developed-it"): the fact is that few methods have been adequately developed. On the other hand there is too much duplication of effort. The real need is not for a bibliography but for a treatise, well-arranged and *discussing* all promising methods.

H. C. ROBERTS

The specific need was for an author equal to a committee in scope of experience and better than a committee in discrimination. As far as I know, only one man qualifies: Howard Roberts has been engaged since 1932 in just the right kind of research and development—specializing in electric gaging but applying the fruits of his work to wide industrial fields ranging from geophysics to railroad tracks, from photometry to molded plastics. He began this book project in 1941 when he was not connected with the University; his work on it is not part of his University duties and (fortunately for our readers!) it is entirely separate from his special war work. That is why his title ("Research Associate") cannot appear at the top of this page—which must break his heart because he is a loyal Illinois grad (B.A. in Physics) and his first job was that of research assistant in the Physics Department, from 1930 to 1932. Between 1932 and 1942 he worked for the State of Illinois and for private industry. In 1942 he was appointed to his present position.

Since 1932 his experience has been mostly commercial research and development of improved methods and apparatus for making physical measurements. He made a name for himself as a designer and builder of so many "gadgets that work" that all the pictures in Part One of his book could be those of his own brainchildren! Of course, he will describe commercial instruments in Parts Two and Three.

(By the way, manufacturers of little-known and never-publicized special instruments and auxiliary devices are invited to send him technically-correct descriptions. His address is 108 Talbot Lab.)

Although Mr. Roberts had amassed a good deal of material before Pearl Harbor, he makes his final revisions from month to month, so that every instalment of his book will be truly up-to-date. —M. F. BEHAR

AUTHOR'S FOREWORD

MEASUREMENT is the basis for all engineering test work. It has been the effort of engineers for many years to increase the sensitivity, the accuracy and, above all else, the utility of their methods of measurement.

The need for methods of physical measurement which would indicate the action of a complete structure or of any portion of it under actual service conditions, though realized centuries ago perhaps, has not until recent years been satisfied. In the last few decades, however, a large amount of work has been published (and there is much more, not necessarily less valuable, not published) describing the principles of such methods, their practical embodiments, and some of their applications.

Three requirements peculiar to such testing methods (and not to the methods ordinarily used in the research laboratory) are of primary importance in structural testing. They are: first, robustness and stability—insensitivity to unwanted disturbances—to make field operation possible; second, ability to record the data being taken at some point remote from the point of application of the gage; and, third, ability to record rapidly-changing phenomena, so that dynamic effects can be studied.

Early in the development of these methods, gages employing pneumatic, hydraulic and mechanical principles were used. Later, electrical principles were applied; these have shown the greatest promise of all. To a large extent, however, the development of electric gages has awaited the concurrent development of the art of application of electrical instrumentation in general. For example, the use of a capacitance-type pressure pick-up (a condenser-microphone telephone transmitter) was suggested[1] as long ago as 1881; its successful application did not come until almost four decades later, after the electron tube had been given practical form.

In structural testing (as contrasted to the usual types of research laboratory testing) far more is required than a set of instruments capable of measuring physical magnitudes in the surroundings of the laboratory. Many of the standard laboratory tests are set up only as means of comparing the characteristics of materials, or of comparing the effects upon those materials of changes in shape; they usually employ as a criterion some factor whose measurement is facilitated by the type of specimen and of testing method used. Translation of such data into structural design is neither direct nor satisfactory.

In contrast to this, the testing of complete structures requires the exercise of ingenuity and imagination. The type of test made must be so chosen that the needed information may be secured without altering the structure or interfering with its action. Sometimes a single measurement can serve as a criterion of more than one of the effects being studied. No general method for outlining test work of this type can be stated; it is more an art than a science.

It is hardly possible to list (and certainly not possible to describe) all the individual forms of electric gaging methods which have been used. Many are only modifications of basic forms; often the only differences of consequence are with respect to the manner of application to the structure. Some gages can measure more than one type of phenomenon with no change in construction. Those which represent basic forms, or which describe particular applications which especially stimulate thought are, it is felt, at least mentioned here. References, which make available the details of all these, are included, and a more detailed bibliography is appended.

(1) Anon. Condensateur Employé comme Transmetteur. *La Lumière Electrique*, Vol. 3, 1881, page 286.

PART ONE
PRINCIPLES OF OPERATION

CHAPTER I
INTRODUCTION

The measurements made in engineering test work depend upon the type of specimen being tested and upon the type of information desired. The terminology is not exact. We speak of strain gages, and of extensometers, and usually we distinguish between the two only by the fact that a "strain gage" is one which is not firmly attached to the specimen during the entire period of the test. Throughout these articles, however, the term "strain gage" will be used to designate any device used to measure strain, without regard to its manner of application. The term "extensometer" will be reserved to apply to those instruments which, by virtue of their construction, measure and average strain over more than one gage line, and indicate the average value. The term "strain" will refer to a change in dimension, customarily over a short base-length, and will be given in units of "inches per inch." When referring to the extension of a spring, or to the deflection of a member in bending, the term "deformation" will be used; this term is also used to describe a change in the shape of a body while its volume remains constant. The term "movement" will be used to describe the change in position of a point with reference to any fixed location. When discussing vibration, the terms "acceleration," "velocity," and "displacement" will be used in the manner familiar to most engineers. It is recognized that these terms are not mutually exclusive; they are, however, intelligible, and in their context should leave no doubt as to the precise meaning intended.

In describing those parts of the equipment which display or preserve the measured data, instruments will be described as either indicating or recording. In this context, "indicating" will refer to those instruments which display for visual examination the values measured, and "recording" will refer to autographic methods. The term "meter" will sometimes be used to refer to indicating instruments; integrating devices will be specifically so described.

The three parameters in an electric circuit which affect the flow of current through that circuit are *capacitance*, *inductance* and *resistance*. A change in any one of these will produce a change in the magnitude, or phase, or both, of the current flowing through that or some associated circuit. It therefore would seem possible to utilize such changes, if they could be produced by mechanical effects, as means for measuring such effects, and this has in fact been done. All three have been made bases for gaging systems which measure mechanical magnitudes. Historically, the capacitance-type gage has been the most important, although it is now used principally in pressure pick-ups or in fixed or station-type gages. The inductance type has probably been the most useful one in the past; within its limitations it is still satisfactory. Gages of resistance types (which can be extremely small and light and can have wide frequency response) probably find the most varied applications.

There have also been developed gages whose gaging elements employ still other electrical principles, gages which utilize electric telemetering circuits to transmit data taken by mechanical gaging elements, and gages based on what may be termed quasi-electrical principles.

Devices for measuring and recording accelerations, velocities and displacements of continuously-vibrating parts by means of generated electromotive forces are also available.

In all such systems, however, whether the gaging element is one whose resistance, inductance or capacitance is varied, whether a piezoelectric element is actuated by an applied force, or whether some type of electrical transmitting system is used in conjunction with a mechanical gage, some movement is involved. (There are a few exceptions to this, but they do not affect the classification.) If the measurement is one of strain, movement or displacement, the application is direct. If the required measurement is one of pressure, load, velocity or acceleration, some mechanical element must experience a strain or movement proportional to the magnitude being measured. In other words, the mechanical application of the gaging element is as important as the selection of the gaging element itself.

Electrical indicating and recording systems are now available with greater sensitivity and wider frequency response than their mechanical adjuncts. In stability, absolute accuracy, and robustness, mechanical systems often surpass electrical systems. The designer must correlate the two to produce the most desirable combination possible.

The pick-ups (and by this term is meant the strain gage head, or other device which is installed at the point of measurement and which serves to convert the mechanical movement into a change in an electrical system) may be extremely simple in construction, and those found most satisfactory in use have generally been the simplest. For static measurements, the auxiliary apparatus may not be complex or expensive, but if the measurements are of dynamic effects the size, cost and complexity will be greatly increased. Yet, for greatest utility of the data, dynamic measurements are often required. If dynamic phenomena —especially inertia effects—are to be studied, continuous recording is frequently the only means by which the necessary data can be obtained. Even if the tests are essentially static, but are made at many points on a complex structure, it may be economical to provide some recording facility, to save time in operation and to minimize errors of observation. For this type of recording, the equipment can be simpler and less expensive than the continuously-recording oscillographs which are necessary for true dynamic testing. The most adaptable equipment, of course, is of the continuously-recording type.

Extremely wide frequency response is required for some types of testing; it may extend from static conditions to frequencies far above the audible range. Most engineering test work is handled with equipment which indicates accurately only those frequencies from zero to about 1,000 cycles per second. This narrower range of frequency response simplifies the equipment by a considerable factor; as a rule, equipment for the higher frequencies is installed only where specifically needed. The present state of the art is such that it often is more economical to purchase one type of equipment for static measurements, another type for test work involving frequencies below 1,000 cycles per second, and a third type for the higher frequencies.

It may even be said that at present the electric gaging systems are in an uncoördinated condition; it is necessary to discuss the several types separately, and sometimes the categories necessarily overlap. This state of things is common to all young arts or sciences; it is only through their normal development that satisfactory coördination is accomplished. And it is largely through dissemination of information regarding methods that orderly and efficient development proceeds.

OUTLINE OF "ELECTRIC GAGING METHODS"

Part One—Principles of Operation.
- Chapter I. Introduction.
- Chapter II. General Principles.
- Chapter III. Capacitance-type Gages.
- Chapter IV. Inductance-type Gages.
- Chapter V. Resistance-type Gages.
- Chapter VI. Miscellaneous Types of Gages.

Part Two—Auxiliary Circuits and Recording Devices.
- Chapter VII. Indicators and Recorders.
- Chapter VIII. Power-supply Equipment.
- Chapter IX. Computing Devices.

Part Three—Operating Techniques.
- Chapter X. Methods of Application.
- Chapter XI. Calibrating Methods.
- Chapter XII. Errors in Actual Use.

Individuals, companies and institutions having information on little-known methods, or on novel and useful applications of well-known methods, are invited to communicate directly with the author: H. C. Roberts, 108 Talbot Laboratory, Urbana, Illinois.

CHAPTER II

GENERAL PRINCIPLES

The gaging methods herein described are most useful to the civil or structural engineer and the stress analyst. They are of use to others, principally because they can be extended or combined with other devices, and thus can assume other tasks. But this treatment will deal only with the use of such gaging methods to measure the mechanical magnitudes which are of interest to the engineer in his study of structures, and emphasis will be placed on those measurements which cannot be made with the gages ordinarily found in the laboratory.

The magnitudes measured include strain, force, movement, and vibration and its components. More than one of these may be present at the point of measurement, and the gaging system must distinguish between them. Thermal expansion, for instance, must not be allowed to affect a measurement of strain caused by applied force.

Measurements made upon laboratory specimens usually are made with instruments designed for the specific test being made. For example, the strain in a specimen in a standard tension test is often measured with a gage which measures the strain along two diametrically opposite gage lines, averages the two values, and indicates on a dial the average extension or strain. This extensometer is attached to the specimen throughout the test, which requires only a few minutes. No temperature correction is needed.

Specimens of irregular shape or size, or in inconvenient locations, may not accept such standard instruments, and in such instances, a portable strain gage is often used. Such gages employ mechanical leverages to provide magnification, and indicate upon a dial; ordinarily they are applied to the specimen by pressing the pointed feet of the gage into small holes drilled or punched at the proper locations. The difference between readings on successive applications of the gage is taken as a measure of the strain. If the test period covers sufficient time for temperature changes to affect either specimen or gage, an unstressed reference bar is used to determine the temperature strains.

With the usual forms of portable strain gage, measurements may be made to an accuracy of perhaps 0.0002″ with care. If the gage base-length is five inches, this will permit measurement of strain to 0.00004″, corresponding to a stress in steel of about 1,200 lbs./in.^{2}. Greater sensitivity is obtained with gages of longer base lengths.

Movements may be measured with virtually the same devices used for measuring strain, although usually the magnitudes being measured will be greater.

Indication of position is another phase of measurement of movement.

Direct measurement of stress is not ordinarily attempted; instead, it is common practice to evaluate the stress in a member by measurement of strain and by computation. Some gaging methods measure stress along perpendicular gage lines and provide values representing stress magnitudes in fields of combined stress.

Force can be measured in terms of the strain produced in a weighbar of known characteristics. This method is suited especially to measurement of rapidly-varying forces.

Measurement of pressure, or force per unit area, is commonly accomplished by measuring the displacement of a deformable diaphragm, capsule, or bellows. Any device capable of measuring small movements can be applied to measure pressures.

The measurement or recording of vibration presents a somewhat different aspect from the others listed, since the important aspect of vibration is its dynamic effect. A static condition of vibration can hardly be imagined. In equipment for vibration measurements, therefore, emphasis must be placed on ability to respond to dynamic effects. Often it is desirable to make available some type of analysis of the vibratory motion. This may involve frequency, amplitude, velocity, or acceleration, or more than one of these. If the wave-form of the vibratory movement is known to be sinusoidal, it is sufficient to measure only the frequency and the root-mean-square value of amplitude. If the vibratory movement is non-repetitive, no matter what its wave-form, recording is the only satisfactory means of procuring the data needed. Simplicity in equipment is encouraged by employing pick-up devices sensitive to one component and introducing electrical integrators and differentiators to evaluate the others.

Measurements of vibration may be applied to either of two types of investigation: they may be used to determine the vibrational characteristics of structures or machines in order to correct or improve their performance, or they may be made upon stuctures caused to vibrate by applied external forces in order to determine the dynamic characteristics of these structures. This second type of measurement is often called dynamic testing. It is frequently applied to buildings, to other large structures and to foundations.

Temperature is commonly measured by thermocouples, by expansive-metal or expansive-fluid thermometers, by resistance thermometers, and by other means. The methods are well established.

In the transfer of testing methods from the laboratory where standard specimens are used to the field where a complete structure is tested in service, several changes in the requirements of the measuring equipment become apparent immediately. First and foremost in these requirements is the question of stability and reliability.

In laboratory testing it is not uncommon to have available several related measurements upon a test specimen, if that specimen requires more than the basic load and strain measurements. It is then possible to check the data from these measurements one against another. In field testing, the contrary condition is likely to obtain: there may be far too few measuring channels available, and it is seldom that measurements can be duplicated. It therefore is essential that the instruments be reliable, that they maintain their calibration and their accuracy under operating conditions, and that their accuracy under those conditions be known.

In field testing, several disturbing factors which do not occur in the laboratory are usually present. Large and rapid changes in temperature, for example, are the rule rather than the exception. Vibration usually is present, and often of extreme severity. Atmospheric conditions cannot be controlled, and the time for making the tests cannot always be selected with regard to the most favorable conditions. The measuring methods must therefore be unaffected by outside disturbances.

Electric gaging systems are especially applicable to field use, because of the ease of providing dynamic response and remote-recording facilities. Their sensitivity can be made high, and even in field application their accuracy can be kept good; just how good depends principally upon the skill and care exercised. Dynamic recording and multichannel operation serve to provide checks upon the operation of the equipment. Of the several types of electric gages available, each has its particular advantages for certain applications. None is perfect. Experience is the best basis for selection of methods, but a fund of information concerning previous work is a substitute to some extent for experience.

Lord Kelvin used to tell his students, "Obtain a measurement, however rough, then endeavour to get a better." That is the philosophy followed by the men who developed the methods described here; it is still a good one to follow.

CHAPTER III

GAGING METHODS BASED ON VARIATIONS OF CAPACITANCE

Pick-up Devices

Gaging systems based upon variations of capacitance are among the oldest of the electric gaging methods, and have been applied to a wide variety of measurements.

The gaging elements, or pick-up devices, used in these systems may be based upon any one or any combination of these actions:

1. Variation of capacitance by change in separation of elements.

2. Variation of capacitance by change in area of elements.

3. Variation of capacitance by change in the specific inductive capacity of a dielectric.

The first of these has received the widest application.

The capacitance of a parallel-plate capacitor is directly proportional to the specific inductive capacity of the dielectric and to the effective area of the plates, and is inversely proportional to the separation of the plates. It may be expressel mathematically thus:

$$C=0.2248\ KA/d \text{ micromicrofarads}$$

where C represents the capacitance in micromicrofarads, K the specific inductive capacity of the dielectric (dimensionless), A the effective area of the plates in square inches, and d their separation in inches.

The simplest type of capacitance pick-up is composed of two parallel plates separated by an air space, and is attached to the specimen in such a manner that the strain or movement being measured will cause a change in the distance separating the two plates. Fig. 1 is a photograph of such a pick-up. The construction is clear from the photograph; the device is a steel member with one circular plate attached near one end, but electrically insulated from the specimen, and with another similar plate attached near the other end by brackets which place the flat surfaces of

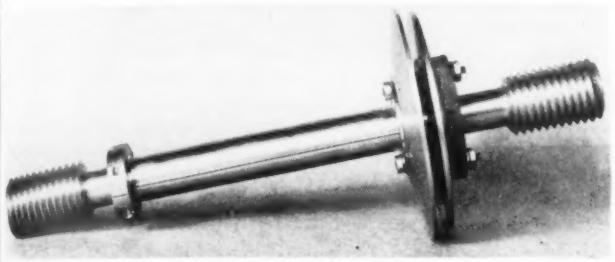


Fig. 1. Capacitance-type Weighbar.

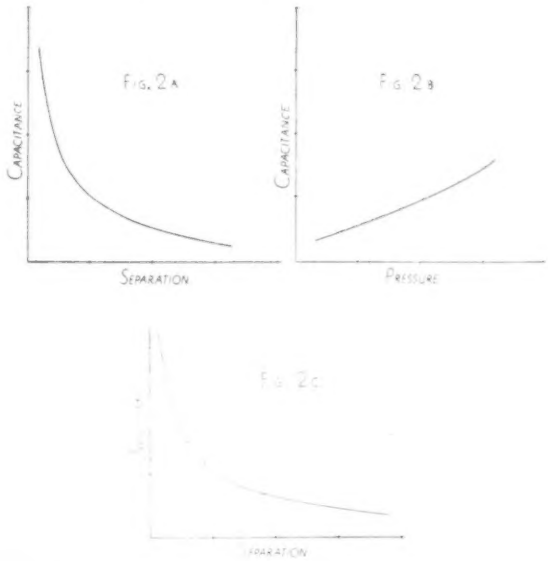
Editor's Note—All devices illustrated in Part One are from the author's own collection; many were designed and constructed by him.

the plates close together, and hold them concentric and parallel.* When the plates are adjusted to a spacing of 0.025", a strain of 0.001 in./in. over the 5" base-length will cause a change in this spacing of 0.005", and a change in capacitance of approximately 20 percent. Some eccentricity may occur, but since the grounded plate is slightly larger than the insulated one, this will not affect the capacitance; if bending of the specimen occurs, the plates will no longer be parallel, but for small amounts of bending the device will simply provide an average value. This unit has been used as a weighbar for measuring varying loads up to 100,000 lbs. The electric circuit is insensitive to outside disturbances, and no shielding is used.

The two-plate type of capacitance pick-up may be constructed in mechanical forms suited to many different measurements. For measuring fluid pressure, one of the two plates may be replaced with a flexible diaphragm, to which the pressure is applied. The resultant deflection of the diaphragm changes the spacing between the diaphragm and an insulated electrode which is the other of the two plates of the pick-up. Since during deflection the diaphragm does not remain plane and parallel to the stationary electrode, the simple relation stated above is not accurate. For small deflections of the diaphragm, the capacitance change can be estimated, but such pick-ups should be calibrated experimentally.

Pressure pick-ups of this type will respond to the most rapid fluctuations of pressure; the limit of frequency response is set by the natural frequency of the diaphragm. This natural frequency can be made to approach 100,000 cycles per second. By simple mechanical expedients, the pick-up may be so constructed as to make it possible to adjust the sensitivity by changing the separation of the plates. The mechanical construction of such pick-ups is not difficult, since the applied pressure is confined to one side of an impermeable diaphragm while the insulating material, the electrical connections, and all adjustable elements are placed on the other side.

For the simple parallel-plate capacitance-type pick-up, the variation of capacitance with separation follows the relation plotted in Fig. 2A. For the pressure pick-up shown in Fig. 3, the variation of capacitance with applied pressure is according to the curve of Fig. 2B. In Fig. 2C is plotted the *change* in capacitance against the *change* in separation for the parallel-plate pick-up. The sensitivity of such a pick-up decreases as the spacing increases, while the linearity of its response is improved.



A capacitance-type pressure pick-up is shown in Fig. 3A, and its construction is shown in Fig. 3B. The outer shell and the flexible diaphragm of the pick-up are made of steel, the insulating bushing is a ceramic product, and the other metallic parts are brass. The dimensions of the parts are so proportioned as to eliminate nearly all changes in the

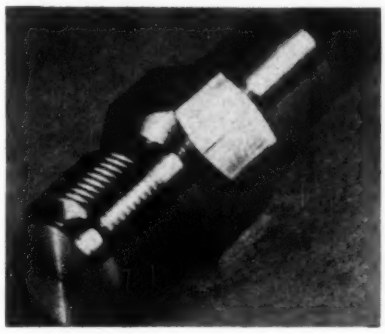
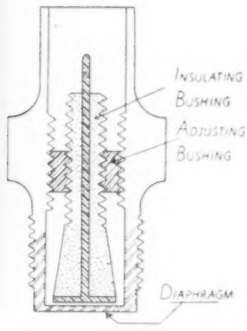


Fig. 3A. Capacitance-type Pressure Pick-up Head.



spacing of the electrodes due to thermal expansion of the parts of the pick-up; its calibration is good over a wide range of temperatures. When used to record cylinder pressures in an internal-combustion engine, there is a steep thermal gradient along the length of the pick-up, and perfect compensation becomes impossible. This shortcoming appears as a shift of zero point for the pick-up.

The two-plate capacitance-type pick-up has several disadvantages. These are the worst ones:

Change of sensitivity with change of plate spacing, or non-linearity;

Change in zero setting with change in temperature, or zero drift;

Change in calibration with change in temperature, or temperature error;

Danger of random and extraneous effects being recorded, or instabiilty.

Careful mechanical design will reduce these.

A modification which improves the pressure pick-up shown in Fig. 3 consists in replacing part of the air in the space between the electrodes by mica. This improves the robustness of the device by adding insulation, the frequency response by adding damping, and the linearity by

*The construction of this device is shown in Fig. 31.

virtue of the electrical properties of the mica. If the entire space were filled with mica, the change in capacitance versus change in electrode spacing would appear as in curve *A* of Fig. 4. If the space is filled with air, curve *B* describes the relation. But with proper proportions of the two, the straight-line response of curve *C* can be attained.[2] The sensitivity is increased, because of the high dielectric constant of the mica. Mica will withstand the heat experienced when applied to internal-combustion engines.

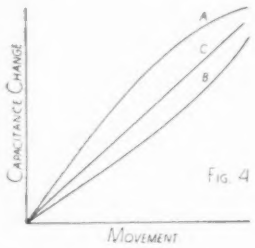


Fig. 4

A gaging element of push-pull type, comprising three plates instead of two, so that one capacitance is increased as another is decreased, is free from several of the disadvantages of the two-plate type. With it, the measurement is made in terms of the ratio of the two capacitances, and changes in their values are of little consequence so long as the ratio between them is not thereby changed. This action reduces or eliminates entirely errors from thermal expansion of the parts of the pick-up, and of changes in any dielectric paterial.

A push-pull pick-up may employ three plates, one moving between two fixed, or may employ four plates, arranged as in the pick-up in the photograph, Fig. 5. The two outer

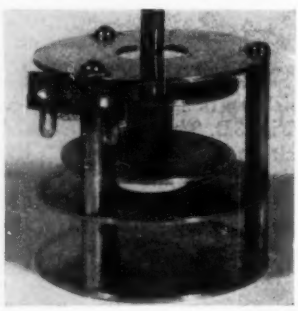
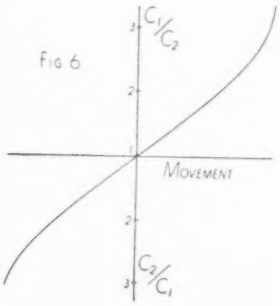


Fig. 5. Capacitance-type Push-pull Position Indicating Pick-up.



plates are fixed and are grounded; they provide electrical shielding for the two inner insulated plates, which move as a unit between the fixed plates. Fig. 6 indicates the variation of capacitance ratio with position. This pick-up has been used as an indicator of balance for a beam-type testing machine. It has a plate separation of 0.25″ and a usable range of 0.15″ in either direction from its central position. By changing the spacing, this range can be made greater or less. Other things being equal, the sensitivity is inversely proportional to the plate spacing.

The push-pull principle is most easily applied to movement gages; it has had little application in pressure pick-ups.

The three pick-ups just described have been sensitive to movement; the measurements made with them were of strain, pressure, and position or displacement. Acceleration can be measured in a similar manner. If a mass is suspended by an elastic support, acceleration will displace the mass until the force due to the acceleration is balanced by the elastic reaction of the suspension. The displacement is then a measure of the applied acceleration. Accelerometers of this type have been applied especially to the study of earth movements and the acceleration of gravity.[3] One laboratory has used such a device, employing a single suspended mass but three capacitance-type displacement pick-ups set mutually at right angles, to record the accelerations in the three coördinate axes simultaneously.[4]

(2) C. H. W. Brookes-Smith and J. A. Colls. Measurement of Pressure, Movement, Acceleration and other Mechanical Quantities by Electrostatic Systems. *Journal of Scientific Instruments* (London), Vol. 16, 1939, pages 361-366.

(3) G. A. Irland. A Study of Some Seismometers. *U. S. Bureau of Mines Technical Paper No. 556*, 1934.

(4) E. Sachsenberg and W. Osenberg. Neure Messverfahren fuer Werkzeugmaschinen. *Zeitschrift Verein deutsche Ingenieure*, Vol. 76, 1932, pages 262-268.

In certain applications it is desirable to have a capacitance-type pick-up with a low intrinsic sensitivity; for instance, it may be necessary to adapt an existing electric circuit to the measurement of large displacements. This requirement is easily met with a variable-area pick-up. Such a pick-up may be an assembly of telescoping metal tubes, insulated one from the other: several inches of displacement (or several feet) may then be measured. Torsional displacements can be measured with a variable-area pick-up constructed on the principle of the ordinary rotary-plate variable capacitor. Care must be taken in designing these pick-ups to insure that no change in separation occurs in operation.

Gaging systems in which the specific inductive capacity of the dielectric is varied by pressure or some other phenomenon have had limited application. This effect is usually small, and with some materials erratic. In industrial plants the principle has been successfully applied to such problems as continuously measuring the thickness of soft materials such as rubber, continuously measuring the moisture content of paper, textiles, etc.[5] If power factor (proportional to dielectric loss) is used as a criterion in addition to capacitance, the method is more useful.[6]

Electric Circuits

The function of an electric circuit associated with a capacitance-type gaging element is to convert change of capacitance into change in voltage, current or frequency, and to indicate or record these changes.

There are two general methods by which this conversion can be accomplished. One utilizes the capacitance of the gaging element in an electrically resonant circuit, so that a change in this capacitance will cause a change in the resonant frequency of the circuit and a corresponding change in either a frequency or a current. The other method utilizes the gaging element as a reactance in a bridge circuit, or in some other manner to control a magnitude. Some methods are not easily placed in either of these categories.

The first circuit employing a capacitative gaging element for mechanical measurements was suggested by Whiddington[7,8,9] in 1919 and 1920. In this system (called the ultramicrometer) two electrically oscillating circuits are constructed and coupled together. In one, the capacitance of the frequency-determining circuit is provided by the gaging element; the resonant frequency of this circuit depends upon this capacitance, according to the relation:

$$f = \frac{1}{2\pi (LC)^{\frac{1}{2}}}$$

In this formula, f represents frequency in cycles per second, L inductance in henries, and C capacitance in farads. It is obvious that the frequency of oscillation of the circuit will vary directly as does the capacitance. The other circuit is adjusted to oscillate at a frequency equal to that of the first in its median position. Since the two circuits are

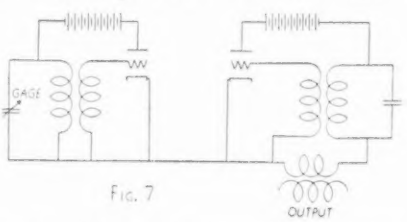


Fig. 7

coupled together, if the frequency of one changes, a beat-note will be produced, and the pitch of this note will be a

(5) H. Olken. An Electronic Tool of Many Uses for Measurement and Control. *Instruments*, Vol. 5, May 1932, pages 113-114, A16-A18.

(6) Anon. Electronic Ice Indicator. *Radio-Craft*, Vol. 14, 1943, page 332.

(7) R. Whiddington. The Ultramicrometer: an Application of the Thermionic Valve to the Measurement of Very Small Distances. *Philosophical Magazine*, series 6, Vol. 40, 1920, pages 634-639.

(8) Anon. The Ultramicrometer. *Engineering* (London), Vol. 110, 1920, page 384.

(9) R. Whiddington. British Patent No. 214, 857.

measure of the difference in frequency, and of the change in capacitance of the gaging element.

A diagram of this circuit is shown as Fig. 7. This is the circuit published by Whiddington in 1920, but it can be set up with modern circuit components, and with it movements of less than a millionth of an inch can be detected.

The ultramicrometer may be used in either of two ways. It is best as a null instrument, and is so used by placing a calibrated variable capacitor in the comparison oscillator circuit and adjusting to zero beat. It may also be used by measuring the beat frequency (by comparison with a calibrated oscillator) and computing the change in the capacitance of the gaging element. The oscillation frequencies are high (of the order of 1,000,000 cycles per second) and the instrument is sensitive, but quite tedious in operation.

In spite of the difficulty of operation, the ultramicrometer circuit has decided advantages for indicating the first occurrence of motion. By careful circuit design, the use of a tuning fork to standardize operating frequencies, and the use of harmonics of the oscillation frequency to reduce "pulling-in," high sensitivity and stability can be attained simultaneously.[10]

The operation of the circuit has been simplified by subsequent modifications. In one of these[11] a telephone receiver is used as a balance indicator and, because of its insensitivity at low frequencies, the circuit is adjusted so that at balance the heterodyne note is 1000 cycles per second, and this frequency is compared to a standard separately generated 1000-cycle note. In another, the audio note is converted into an amplitude variation in a nearly-resonant circuit.[12]

An early modification of the device made the change in frequency of the oscillating circuit appear as an indication on a galvanometer; this made it satisfactory as a deflection-type instrument.[13, 14] The operation of this circuit, shown in Fig. 8, depends upon the fact that the average anode current of the oscillating tube varies as the ratio of inductance to capacitance in the tuned circuit is changed.

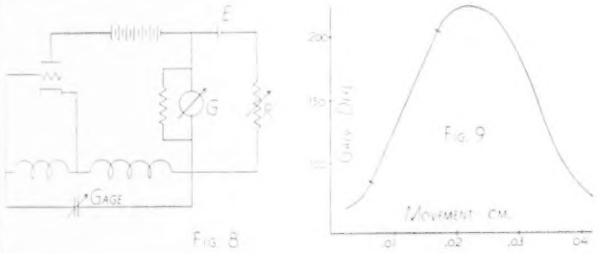


Fig. 8

This change in anode current is small compared to the total anode current, so that it is necessary to measure the change rather than the total current. To accomplish this, the resistance R' and the battery E' are introduced, and so connected that the normal anode current flowing through the galvanometer G is just balanced by the steady current in the opposite direction from the battery E'. Deflection of the galvanometer then indicates change in anode current, and therefore the magnitude of the effect being measured. The type of calibration curve provided by this circuit is shown in Fig. 9.

The circuit has these advantages over the one of Fig. 7: it is less tedious to operate, and it indicates the direction of change as well as its magnitude. But it is not as sensitive, since it does not take as full advantage of the resonance principle.

An entire series of closely related circuits of this type has appeared, all utilizing the resonance principle and actuating an indicating instrument. Some employ two resonant circuits; one such is diagrammed in Fig. 10. A single oscillating electron tube is used, with one resonant circuit connected in its plate circuit, and another in the grid circuit; the two are inductively coupled together. The amplitude of oscillation depends largely upon how nearly alike the two circuits are tuned; if they differ slightly, a change in tuning will produce a change in the plate current of the tube. When the adjustment is correctly made, an increase

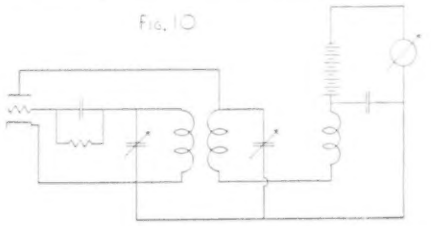


Fig. 10

in gage capacitance will cause an increase in plate current, and a decrease in capacitance a decrease in current. The steady component of the plate current is balanced out (as previously explained) and some filtering introduced, to keep the high oscillation frequency out of the indicating device. This circuit will operate either a pointer-type indicator or a recording galvanometer.

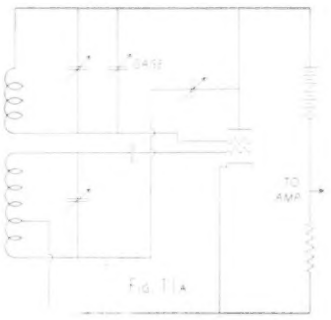


Fig. 11A

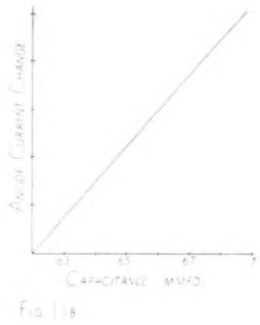


Fig. 11B

Still another form of this circuit, employing a single multi-element electron tube as a tuned-grid tuned-plate oscillator and vacuum-tube voltmeter, is shown with a typical calibration curve in Fig. 11, A and B. It provides a large current output.[15, 16]

Whenever resonant circuits are coupled together, there is danger of self-synchronization, or "pulling-in." This introduces errors, greatest near the point of normal synchronization, which is just where such errors are most

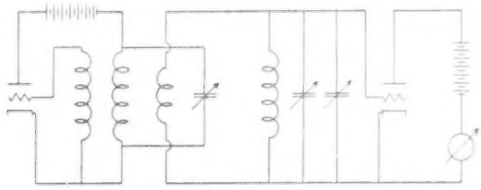


Fig. 12

troublesome. To avoid this danger, coupling is made "loose." In the early circuits, shielding and mechanical separation of circuit components were used. An improved circuit[17] designed especially to minimize errors from this source, is drawn as Fig. 12. It incorporates a separate adjustable coupling coil, so that any desired degree of coupling can be arranged. The form of calibration curve obtained is shown in Fig. 13; its symmetry indicates good adjustment of the circuit.

The actual capacitance of a gaging element alone is small (about 60 mmfd. for the pick-up shown in Fig. 1) while the capacitance of the leads connecting it to the rest

(10) H. Lloyd. Note on an Application of the Whiddington Ultramicrometer. *Journal of Scientific Instruments* (London), Vol. 6, 1929, pages 81-84.

(11) L. Pungs and G. Preuner. Verfahren zur Messung sehr kleiner Kapazitatzen und Induktiven. *Physikalischer Zeitschrift*, Vol. 20, 1919, pages 543-545.

(12) W. W. Loebe and C. Sampson. Beobachtung and Registrierung duenner Draehte. *Zeitschrift fuer Technische Physik*, Vol. 9, 1928, pages 414-419.

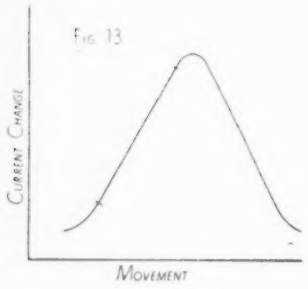
(13) John J. Dowling. The Recording Ultramicrometer. *Engineering* (London), Vol. 112, 1920, page 395.

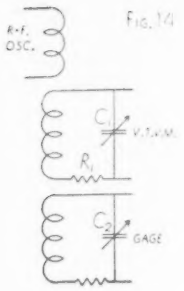
(14) John J. Dowling. The Recording Ultramicrometer: its Principles and Application. *Philosophical Magazine*, series 6, Vol. 46, 1923, pages 81-100.

(15) G. Gustafson. Ein verbessertes Ultramikrometer nach Dowling. *Annalen der Physik*, Vol. 22, 1935, pages 507-512.

(16) W. D. Oliphant. On the Use of the Pentode Valve for Pressure Recording. *Journal of Scientific Instruments* (London), Vol. 9, 1932, pages 386-388.

(17) H. Thoma. Aufzeichnung schneller Schwingungung. *Zeitschrift Verein deutsche Ingenieure*, Vol. 73, 1929, pages 639-642.





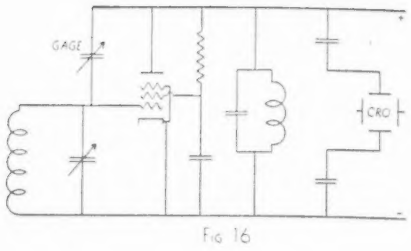
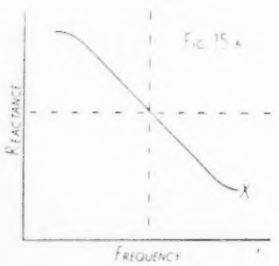
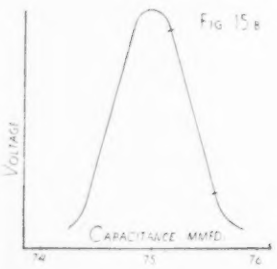


Fig. 16





of the circuit may be several times as large. The effective capacitance in the circuit is the sum of the two. The shunting effect of long leads greatly reduces the sensitivity of the gage circuit, and makes it necessary to provide great magnification of the observed effect. The resonance principle must be employed to the greatest possible advantage.

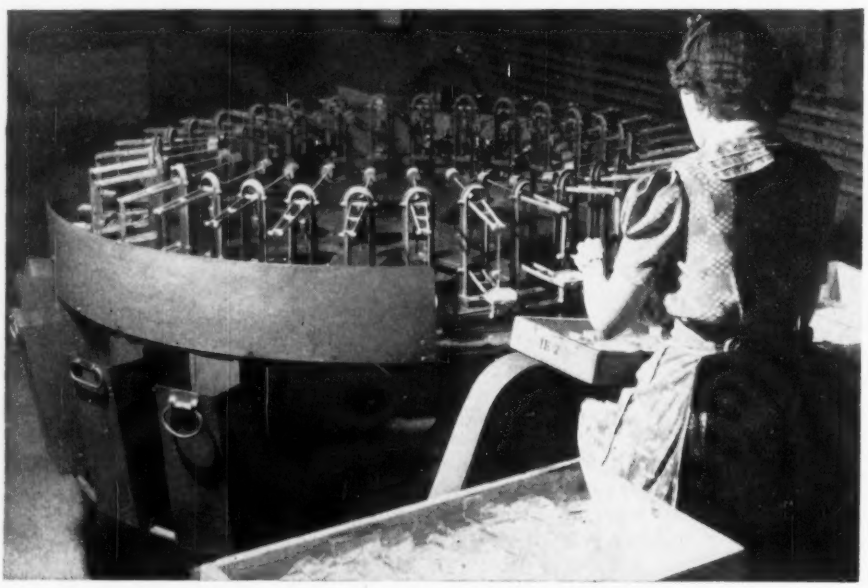
A method by which the greatest possible sensitivity may be obtained makes use of the reactance of two resonant circuits, inductively coupled to each other and to an exciting oscillator. The method is extremely sensitive, although limited in its range. Its principles are shown in the diagram, Fig. 14. A fixed-frequency oscillator is coupled into two resonant circuits; one contains the pick-up; the other is connected to a device which measures the voltage across it. If the coupling between these circuits is adjusted properly, a change in the capacitance of the gaging element will cause a proportional change in the resonant frequency of its circuit; this change will be reflected in the other of the coupled circuits as a change in the voltage existing across it.[18] The shape of the curve describing the relation of reactance to change in resonant frequency is shown in Fig. 15 A, and in Fig. 15 B the output voltage of the circuit is plotted against the change in C_1. It is apparent that the sensitivity of the circuit is high, and the linear range short. It is necessary to maintain accurate adjustment of the circuit if the operation is to be satisfactory.

A recent circuit, employing a novel principle, is shown in Fig. 16. The device was designed for measurement of thickness of insulating coatings, or for small movements, in industrial conditions.[19, 20] It indicates on a cathode-ray oscilloscope or a pointer-type instrument. It is a high-frequency oscillator circuit in which the capacitance gaging element is made a part of the regenerative network so that changes in its capacitance change the amplitude of oscillation of the circuit. A disadvantage of the circuit is the need for insulating both electrodes of the gaging element and for providing shielding for them.

(18) W. D. Oliphant. New Method for Recording Minute Changes in Capacitance. *Journal of Scientific Instruments* (London), Vol. 14, 1937, pages 173-177.

(19) W. Wilson. Applications of the Cathode-ray Oscilloscope in Industry. *Beama Journal*, Vol. 49, 1942, pages 10-14.

(20) Elmer F. Hansen. Concentricity. *General Electric Review*, Vol. 45, 1942, pages 615-616.



Automatic Weigher-sorter Does Work of 20 Men

SPEEDING UP the war effort in the precision lens field is this merry-go-round on ball bearings, carrying an endless procession of balance scales past a single operator, which does the work of twenty individual sorters and weighers in the glass plant of the Bausch & Lomb Optical Co.

Small squares of optical glass, which must be accurately weighed before being molded into lens blanks, are placed on each balance as it passes the operator. The scales are set to weigh within one gram (= 0.035 ounce). Attached to the pan of each scale is a trip lever which automatically dumps the glass into the proper bin.

The heaviest pieces are tripped at the right of the operator, with each succeeding bin receiving blanks weighing one gram less than the preceding one. A bin is provided to take blanks weighing more than the maximum; another for those below the minimum.

There are thirty balances on the machine which makes two revolutions per minutes, weighing and sorting the pieces with each revolution. All the operator does is to place a piece of glass on each scale as it passes. The machine does the rest, sorting each piece by weight.

Dry Electrolytics Standardized

The American Standards Association has announced the revision of the radio war standard on Dry Electrolytic Capacitors (Home Receiver Replacement Type) (C16.7-1943—2nd edition), which was first approved February 16, 1943. The specifications cover the basic requirements applicable to dry electrolytic capacitors suitable for use as replacement parts in home radio receivers. The minimum performance requirements are designed to furnish capacitors which will use as small an amount of strategic materials as possible, will not restrict production and will prove satisfactory from an electrical and service-life standpoint. This standard may be purchased for 20c a copy from the American Standards Ass'n, 29 W. 39th St., N. Y. 18, N. Y.

Instrument Maintenance in an Oil Refinery

By V. H. HIERMEIER, Brown Instrument Co. Div., Minneapolis-Honeywell Regulator Co., Chicago, Ill.

IF you will consider the title of this talk it will be evident that several different subjects could be selected. I have chosen, tonight, to talk about the instrument man, his training, shop, duties, and the importance of his job. It is true that the duties of industrial instrument men, in an oil refinery or other plant, will vary according to the applications, but one thing they must all have is knowledge of the equipment and of the process.

When comparing today's industrial instruments against those of twenty-five years ago, it is evident that instrumentation is a new field. There has been a rapid advance in machines and materials which has made the industrial instrument man's job a tough one, as I will attempt to bring out.

Let us go back to the end of World War I and see what we had in the way of industrial instruments and trained instrument men to work on them in the oil refineries. I need not cite detailed statistics, for you know that the production of ships, airplanes, tanks, and various vehicles in World War I was comparatively small. We make nearly as many airplanes in one month in this country as were used in the entire first World War. At the time we entered this war, automobile production was many times greater than it was twenty-five years ago. Along with the increase in the amount of machines used, their efficiency has been continuously improved. A 60-octane gasoline would have been considered an excellent fuel for cars and planes. The equipment required to make such a product was large and bulky and usually operated with several simple temperature indications, along with a few spot pressures taken over the unit. Today, we cannot operate without the use of entirely automatic control of temperature, pressure, flow, and liquid level. Instruments are doing a job in today's refineries that would be impossible to accomplish with human operators alone.

What opportunities and what type of men did we have available, as an average, to work on the few instruments in these plants? To begin with, there weren't enough instruments usually to warrant one man spending full time to take care of them. Therefore, a man with a flair for digging into something that he knew nothing about was picked for this job. His other duties came first, so this was considered as a tinkering job for him. Usually, it didn't matter much whether the instrument worked right or whether it didn't. The operators on the units were used to getting along without them, and, in most cases, placed little trust in them. Here and there, an operator would be smart enough to see that if he could depend on the instrument, it would allow him more time to do something else, or to rest. If the man who was given the job to tinker with the instruments was unable to place them in working order—even with the help of the operators and of anyone else who happened to be around to make suggestions — then the manufacturer's representative would be called. There usually was a considerable delay, since the manufacturer's representatives were seldom close at hand.

Usually the instrument company would suggest that the instrument be returned to the factory for repairs, because it was such a mystifying piece of equipment that it could only be repaired by trained men in their own laboratories. This would take considerable time, but the instrument didn't mean much in the minds of operators and management! Also, since there were few instruments in a plant, little thought was given to training a man to repair the instruments in the plant with minimum delay.

Another thing that discouraged the plant instrument man was the attitude or policy of most of the instrument companies. In most cases it was difficult for anyone interested in tinkering with instruments to get instruction books to find out something about them. Most of the instrument companies maintained that it would be far better to call in one of their trained men or send the instrument to the factory.

Occasionally, if you had cultivated the friendship of an instrument company representative, you might be able to talk him into giving you small bits of literature on some of the instruments; but you were able to learn little from the mimeographed or printed matter then available to the manufacturer's own employees.

A few years later, when a certain refinery heard that a competitor was able to produce a stable product, day after day, through the use of a flowmeter or temperature recorder, or perhaps a simple controller, then this company would try to do a little better. The next chapter in this brief history was that the increasing number of refinery applications for instruments, with advances in refining, caused instrument companies to set up programs of research and development, until today we find that some of the largest research laboratories have contributed greatly to the winning of the war through wider use of instruments in the refineries.

Let us now go back and see what happened to this instrument man who was doing part-time tinkering with a few instruments in the old refinery. As instruments were added to the process this part-time tinkerer found that he was up against a full-time job, especially since his knowledge of the new equipment that was coming in was very vague. By this time instruction books were normally included with the instrument equipment, but usually those instruction books were filed at the main office of the refinery by someone —perhaps some engineer — who had nothing to do with the actual maintenance and repair of the equipment. By this time, also, there were more instrument-company representatives and they began to feel that perhaps it would be better for them to assist the plant instrument man in his troubles and attempt to educate him a little so that he might look upon this particular make of equipment with a little more favor. It will also be remembered that, since the use of instruments had increased and since they seemed to have a future, other companies were becoming interested in this industrial market. Competition in any field of endeavor, in my opinion, seems to be the spark or push that causes all of us to strive to do bigger and better things. Competition has given instrument users today a wide choice of equipment. Since we do not all think alike, nor react the same to any particular situation, demand for a wider selection of types and makes has progressed extensively. Today we have many large industrial instrument manufacturers. Still, none of them has the ideal instrument for every application, even though some of them may proclaim just that.

Getting back to the instrument repairman again: he has found that the job is too big for one man and he has taken on one or two helpers. He is now being supplied with a little more literature because he does have a lever to use, namely the fact that he is using several makes and can tell one instrument company that another instrument company supplies him with instructive literature; whereupon the first instrument company tries to outdo the other instrument company.

Only eight or nine years have passed since any of the oil refinery managements began to give much thought or time to the education of qualified instrument personnel to care for and protect the investment they have in such equipment. In several colleges throughout the country, just a little education has been included regarding industrial instrument equipment, but not nearly enough to allow a man to come from school and take a job in industry as an instrument engineer. There was no source of supply for industry to secure trained instrument personnel. I am sorry to say that this condition still prevails today. It is true that there are a few trained instrument engineers in the field today; they are, to my knowledge, men who have been trained or have trained themselves through a period of years that were

*Talk delivered before the Chicago Society for Measurement and Control, Monday, December 6, 1943.

very difficult. Many of these men were the part-time instrument men of twenty-five years ago.

Today's increased production has placed a heavy demand on all trained personnel. Since the field of instrumentation is comparatively new, it probably is one of the specialized trades where the demand for trained men cannot be met.

For the past few years, most of the larger instrument companies have maintained schools in their plants where any instrument-minded person could spend a few months. Since we all have to start somewhere in any field of endeavor, this instrument schooling serves as a good start for an instrument man. A school of this kind is operated by a particular instrument company and it deals with instruments manufactured by that company only. The instrument man, after completing such a course, is fairly well-versed in this one manufacturer's equipment, but he finds in most industrial plants today that there are other types and makes than those he studied. This may not be so difficult if the man has a good understanding of the simple fundamentals and theory of measurement and control. If he is mechanically inclined, he may go from one make of instrument to another with little difficulty and be able to render service on the various types and makes in the average oil refinery.

Since the shortage of trained instrument mechanics has been acutely felt during this period of increased production, some of our engineering colleges have finally seen the need for college level training classes in industrial instrument equipment. Some of them are setting up permanent training laboratories so that they will be able to supply our industries with sufficiently trained instrument engineers just as they have been able to turn out electrical and mechanical engineers, etc.

KNOWLEDGE OF PROCESSES

Now that we have the man pretty well trained in the art of repairing the various types and makes of instrument equipment, we run into his second problem, which is just as important. This second problem is the operation which involves the application of the instrument to the process. It is true that while an instrument man is being trained in a plant (and the instruments are in use on the process) he actually gets some training with that process if he is observing enough. Too many of the instrument men today lack that initiative and ability to learn about the process or application of the equipment and only concern themselves with the actual operation of the instrument itself. Today we find more of this type of man than we find men who master the process and application along with the actual mechanics of the instruments. We see, then, that a good instrument engineer not only should be a good mechanic but also must have a good knowledge of the operation of the various types of processes in a plant. It has often been said that a man can only be expected to excel in one field. It is true, however, that since the operation and the application of instruments on that operation are considered as one, then that will give this man his field. It is a broader field than a steamfitter's or a machinist's or a carpenter's, but, in my estimation, a good instrument engineer must master it.

I have had the pleasure of meeting, and in most cases knowing personally, the great majority of the instrument men in the Calumet Region where there are a half-dozen oil refineries. The Calumet Region with its oil refineries, steel mills and other industries—some of them small but in most part using industrial instrument equipment—employs several hundred instrument mechanics. Out of that number of men I could pick out at least two dozen good industrial instrument engineers. In my mind, there are two kinds of men in this field—those who work on instruments and those who are instrument engineers.

THE INSTRUMENT DEPARTMENT

Let us go back now and look into the requirements of a well-equipped instrument department. Up to a few years ago, and even now in some of the smaller plants, instrument men are allowed to run loose over the entire plant without the benefit of proper supervision—at the dictates of department heads who are permitted to request their services. These men, in these smaller plants, share a shop or rather a place to keep their tools, along with some other maintenance group in that plant. They have no special place to work on instruments and, therefore, are required to do most of this repairing on the job. It is true that few plants in these times have many spare instruments to enable them to make a replacement while making repairs on the instrument taken out. However, there are times when it becomes necessary to remove an instrument from its location and bring it to a clean shop where the proper repairs can be made. In the larger plants, such an instrument department is found. It is equipped with most of the necessary testing equipment, workbenches, parts department, and so forth. It must have several departments in itself; namely, a pyrometer division, flowmeter division, clock-repairing division and pressure gage testing and repair division. In some of the larger plants there are men stationed in these shops who are called inside men—their job being to repair the equipment as it is brought in to them by the field men. The men in these shops are usually the older men with more experience which affords a very good opportunity to train the new man. Where this type of department is found, the inside men make their own thermocouples for the plant—a large job when several thousand couples are used throughout a plant.

The outside man is assigned a definite territory in the plant and is responsible for the proper operation of the equipment in this particular territory. This territory may consist of one particular type of unit. On large units there is a sufficient number of instruments to warrant a full-time man. After a while, this man will become thoroughly familiar with the particular equipment and operation of this unit. Thus he becomes very valuable to the operation of that equipment. At the same time, this man is missing a good deal of other applications on a lot of other units throughout this plant. It is customary, then, to move these men around from one location to the other to give them overall training and experience throughout the entire plant, so that they are able to do a good job wherever they may be sent.

It is true that some companies do not like this method of moving one man from place to place, but it has been found to be a definite advantage especailly in these times when men are called to our armed forces or find more lucrative spots elsewhere. The men who are left must carry on and must be even more versatile than before.

In several of the larger plants, even though the main instrument department is more or less centrally located, it is necessary for these individual men in various territories to set up small cubby-hole shops from which they work directly. These shops are usually a part of the unit to which they are attached. They have enough room to take care of their tools, with a few charts and spare parts for the instrument equipment on the unit. This, of course, saves time and, in most cases, saving time means

THIS MONTH'S FRONT COVER

Automatic Control of Synthetic Rubber Process

"The installation is at the Copolymer Corporation, Baton Rouge, La. This plant is government-owned, and operated jointly by seven rubber companies. The product is the standardized Buna-S type of synthetic rubber made principally from Butadiene and Styrene. The instruments shown are only part of those in this completely Taylor-equipped reactor instrument control room. All of the operations in the reactor area are controlled from this room. This is the standard set-up in all of the synthetic rubber plants where this function is performed. The instruments shown are for recording and controlling temperature, pressure, and rate of flow. All of the instruments are equipped with pneumatic alarm systems, the colored lights for which are located directly above each instrument."—W. W. Lockwood, Taylor Instrument Companies.

fewer interruptions in the production of that unit.

An instrument shop or department properly supervised with the proper test equipment, instrument library and sufficient tools and parts to do a good job, is the first requirement for the proper maintenance of instrument equipment in any plant. The instrument shop, however, serves as another important factor in the results obtained from the instrument equipment in the refinery.

DAILY MEETINGS DO GOOD

Since each man or group of men will be out of the central shop most of the day and will not have an opportunity to talk to the rest of the men, the morning and evening meetings of these men in their central shop give them an opportunity to talk over some of the more difficult jobs they have had the previous day or the same day; and at the same time get a few pointers from the other men.

I have found it extremely profitable, from an oil company's viewpoint, to hold fifteen-minute or twenty-minute sessions, both morning and evening, in the central shop for these men. It is not necessary to have them ruled by the supervisor or even for the supervisor to sit in on them. It merely affords them a chance to talk. Of course, a few stories are told—and this goes to make up a congenial atmosphere, which is desirable because when a congenial relationship exists among any group of men, better work and uninterrupted production will be the result. This is not only true of instrument men, it has been proven that it works equally well with any group of people, regardless of occupation—with groups of salesmen, executives, professors, bishops, Campfire Girls, admirals, office boys, or any group whose members serve a common purpose. If the supervisor of any group of men will stop to consider that normally they spend one-third of their time under his supervision, then his supervision must create a congenial atmosphere. It is neither my intention nor my duty to include personnel management in this talk tonight, but I can't help mentioning this particular angle because so many supervisors fail to recognize it.

NEED OF PLANNED TRAINING

The instrument supervisor is faced with the problem of continually training new men, or at least furthering the training of the partly-trained men he has. We have brought out this evening that improvements are continuously being made on existing instrument equipment. Therefore, it is necessary for each man to keep up-to-date or be kept up-to-date. The supervisor must do this himself, since he is often called upon to make suggestions regarding the type of equipment required for certain applications. Even when he is not requested to make these decisions, he will find his department made responsible for this new equipment sooner or later.

In my estimation, a well-laid-out training program should be a part of the instrument supervisor's duties. I think the first step should be to make up a chart of the men in the department. Next to each man's name should be the amount of time he has spent in instrument work, then the amount of time he has spent in this plant's instrument department. Across the top of the chart should be listed the various types of equipment used in the plant. Some of these headings would be flowmeters, pyrometers, potentiometers, thermometers, pressure gages, control valves, clocks, electrical and mechanical CO_2 meters, pH meters, combustion equipment, etc., and perhaps one column headed "miscellaneous." If we run horizontal lines from each man's name and vertical lines from the types of instruments involved, we end up with rows of "boxes" in which to insert the amount of time each man has spent with each type of instrument. [See example on this page.]

PROGRESS RECORD

	Plant Time	Dep't Time	Flow-meters	Pyrom-eters	Potenti-ometers	Therm-ometers	Pressure gages	Air-op. control	Control valves	Other Control	Clocks, etc.	Misc. (name)
Jones	8 yrs.	3 yrs.	Test OK 5-1-41 8 mos.	1 yr. ?	1 yr. ?	6 mos. ?	Test OK 1-2-42 18 mos.	6 mos. ?	2 mos. ?	None	None	
Smith	2 mos.	2 mos.	None	None	None	None	1 mo. ?	None	None	None	None	
Wood	6 yrs.	6 yrs.	Test OK 6-1-39 2 yrs.	Test OK 5-2-37 5 yrs.	Test OK 5-2-37 5 yrs.	Test OK 6-3-42 3 yrs.	Test OK 5-4-35 1 yr.	Test OK 5-3-38 1 yrs.	Test OK 5-3-40 2 yrs.	Test OK 6-3-39 5 yrs	Test OK 2-2-40 4 yrs	
White												

REMARKS—Jones will arrange for tests in Pyrometers and Potentiometers, June 6.

To start this record, it will be necessary for the supervisor to test each man, especially the older ones, to determine what to fill in opposite each name. As an example, John Jones has passed a test that shows he has had sufficient training in flowmeters and potentiometers. The time that he has spent admittedly by himself in these two fields should be marked in months or years in the proper box. If, however, he isn't able to pass the required test, the time he has spent is still written in, but with a question mark or some other symbol showing that this man is requested to complete further study along these lines. The vacant boxes will show that this man needs training in these particular brackets. Time schedules can be made up, whereby each man automatically comes up for his test in one or more brackets periodically.

Since this chart is kept out in the open where all may view it, it will tend to cause each man to work harder toward filling his boxes until he has a full row of qualifications opposite his name. As new men come in to the department, it is up to the supervisor to guide each one in his selection of proper training procedure, that is, to start him out with a simple type, or with the fundamentals of theory of instruments for the first few months. It is true that he will be working with some of the older men, preferably in the shop, and a lot of his questions that arise from reading can be answered by these men or by the supervisor. At this point I again call your attention to the importance of a suitable, complete, instrument library, including books on instrumentation along with instrument companies' literature on various types of instrument equipment.

It may be advisable for the supervisor to keep an individual record of the advancement, background, training, etc., of each of his men. Personal notes may be made to his card file and, of course, kept more or less personal by the instrument department supervisor.

With the chart that we have just discussed, along with the personal record on each man in the department, the supervisor knows just about at a glance how each of his men stands and how each is progressing. I cannot put enough emphasis on the necessity of an instrument man's knowing the fundamental theory of instrumentation, before he gets too deep into the actual repairs of that equipment. You will find that a man starting out in this field will be more easily led through the simple theory and fundamentals of instrumentation if given that education before he has had a chance to do too much repairing or tinkering on the actual instrument itself. A mechanically-minded person, if given the opportunity, will attempt to further his knowledge in repairs of the equipment rather than retrogress into the fundamental theory behind the development of the equipment with which he is faced.

ACTUAL EXAMPLE SHOWS VALUE OF KNOWLEDGE OF THEORY

As mentioned before, so many of our instrument men today have never had the opportunity, or at least have never taken the opportunity, to revert back into the fundamental theory of the equipment they have been working with for years. Therefore, their job is by far much harder than if they had in their minds a clear knowledge of the principles and theory of this equipment.

Let me cite just one example of this. It is common practice to fire a pipe still in an oil refinery by using a pressure-loaded gas valve of the balanced type whereby the downstream pressure of the gas line is attached to the bottom of a diaphragm and a loading pressure from a temperature control instrument is set on the top of that diaphragm. The temperature-sensitive element of the control instrument is located in the outlet oil of the still. If the loading pressure from the temperature control instrument remains the same and the pressure in that line changes because of other plant requirements on the gas

(Continued on page 230)

The Constitution of Matter

How Is The Universe Put Together and What Holds It Together?

A Refresher for Instrument Men

By S. R. WILLIAMS, Professor of Physics, Amherst College

Before advancing to other subjects in Mechanics, such as elasticity, friction, surface tension, gravity, etc., it would seem to be a logical step to digress and talk about the forces which hold matter together, as in solids and liquids, or why gases behave as they do. When we come to the compression or the stretching of a piece of steel we are dealing with interatomic forces and some preliminary survey should be had if we are to have a clear understanding of these mechanical phenomena. What holds the molecules or atoms together in a soap film? These are fundamental questions to a better understanding of some of the physical phenomena to be discussed.

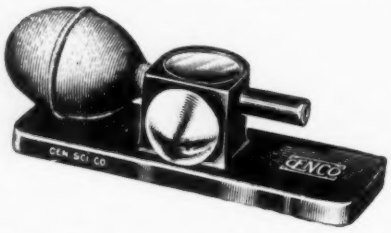


Fig. 1. Brownian Movements Apparatus.

(Courtesy Central Scientific Co.)

As we look out on the world in which we live, we are conscious that it is made up of at least three states of matter: solids, liquids and gases. Solids are known by their resistance to change in form, liquids by assuming the shape of the containing vessel and offering a free surface, while gases are recognized by their powers of indefinite expansion.

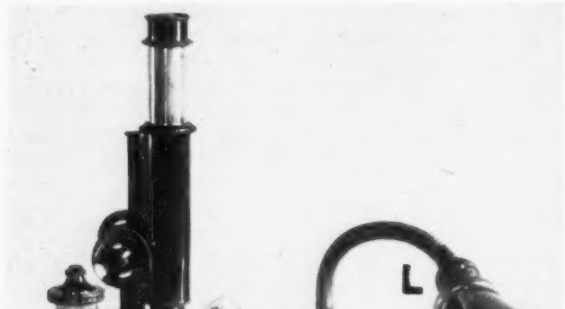


Fig. 2. The Brownian movement cell in Fig. 1 is mounted under a microscope. The light from the electric lamp illuminates the smoke particles in the cell.

Our picture of a gas is of a large number of small particles, darting hither and thither, with a great deal more space between the particles than is actually occupied by the particles themselves. In the expansion of the gas we simply mean that the space between the molecules increases. The actual volume of the gas particles changes little relatively. How do we arrive at this picture of a gas?

Demonstration of the Brownian Movements

The easiest way to show this ceaseless dance of the molecules of a gas is to look with a microscope into a small volume of gas in which smoke particles are suspended. While the molecules of the gas cannot be seen with the microscope, the smoke particles can. Fig. 1 shows the little receptacle in which the smoke particles are suspended. Light a match and let it burn until it is going well, then blow it out. Smoke arises for a second or two from the burnt match which may be drawn into the receptacle by means of the small rubber bulb attached.

On focusing the microscope into the interior of the small receptacle, there will appear in the field of view the particles of smoke zigzagging here and there, as though they were being pushed first in one direction and then in the other. Fig. 2 shows the small receptacle in Fig. 1 placed under the objective of a microscope. A small lens in the side of the receptacle concentrates the light from the lamp *L* on the smoke particles. Fig. 3 will indicate a little the type of motion one observes. Furthermore, we observe that the smaller the particle the more it seems to be bumped around. This follows from the idea that if the particle is large it is just as liable to be bumped in one direction as in the other and so it appears not to be bumped at all, whereas if the particle is tiny the probability is that if given a kick on one side it won't be opposed on the other and so appears to be pushed in that direction. If the smoke particles are being pushed around we assume that the molecules of the gas are being disturbed even more.

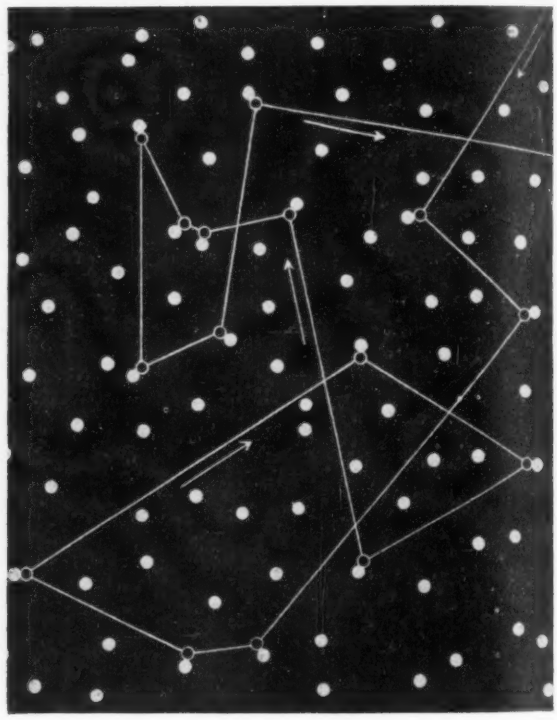


Fig. 3. The path of one molecule is visualized while the others are held in their positions. Of course, all the molecules are in a state of ceaseless agitation.

These Brownian movements have been photographed by movie cameras and can be shown to a large group by means of a film projector. To show by ordinary microscopic projection is much more difficult because the light intensity is cut down by the small aperture of the micro-

Preceding "refreshers" by Dr. Williams:
Dec. '42—"Metrology, the Science of Measurement."
Mar. '43—"Principles of Mechanics."
Oct. '43—"Vibratory Motion."
Nov. '43—"Dynamics."
Dec. '43—"Forces Involved in Curvilinear Motion."
Don't write to *Instruments* for back copies: paper restrictions prevented printing peace-time overruns.

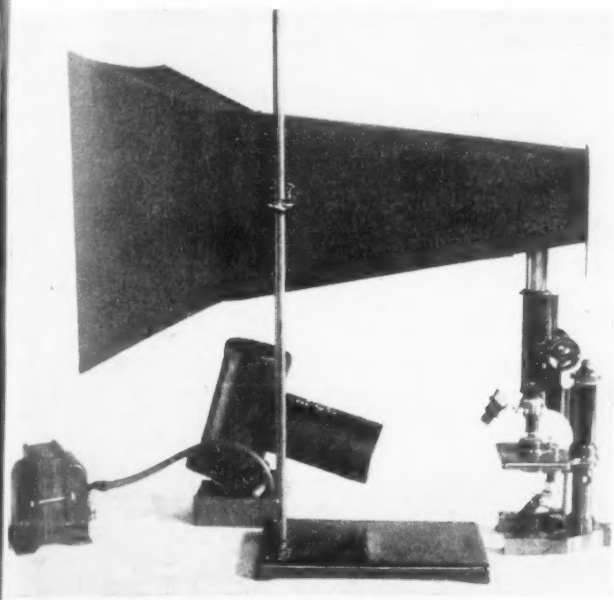


Fig. 4. Microscopic images of the Brownian movements are projected on a ground glass screen in the hood.

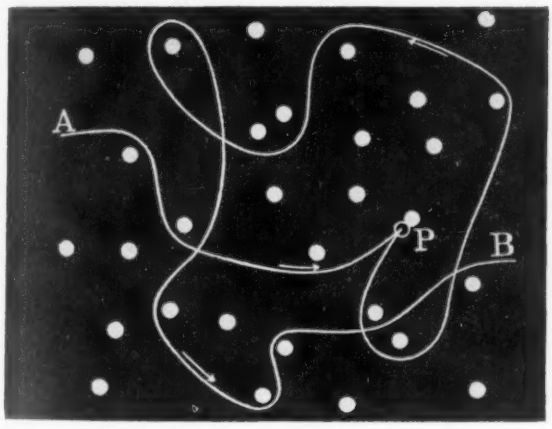


Fig. 5. Brownian movements in a liquid.

scope objective. For small groups the outfit shown in Fig. 4 can be used fairly satisfactorily. Here the screen is a piece of ground glass about 16″ square and all extraneous light must be excluded from around the viewing screen.

Some claim that they can project finely ground particles of mica suspended in water. In this case the receptacle must be made up of a cell with parallel plate glass sides so that the light may be projected through the mixture. In any case it is not easy to project and the simple method described at the beginning is satisfactory for the individual observer.

The fact that the Brownian movements of mica in water may be shown, suggests at once that even in water there is enough space between the particles so that in the water or other liquids the particles may be bumped around as in gases, but not to such a degree as in the gases. The particles are closer together and hence influence one another so that the particle once bumped doesn't go as far in a liquid as in a gas. This can be verified by the method described for observing the Brownian movement. See Fig. 5.

The next question which confronts us is—Is there interstitial space between the particles composing a solid? Is there any free space to be found in a solid like a piece of steel, for instance? If so, what are the forces which hold the particles together? These are extremely important

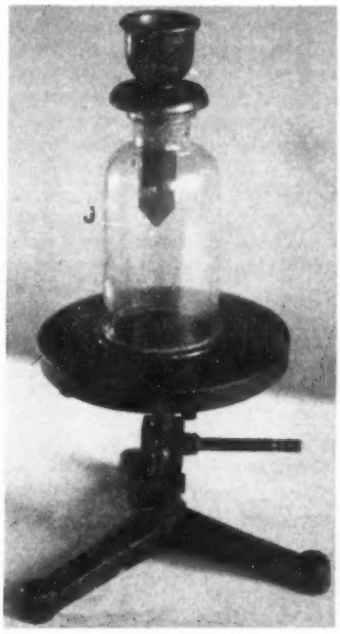


Fig. 6. Mercury can be sucked through the wooden stopper, showing that though it is a solid, it possesses the property of porosity.

questions and could we answer them specifically we would clear up many problems which now trouble us about various properties of matter in general.

Is there free space between the particles making up a solid body? The fact that a tiny bit of musk placed in a room soon sends out an odor of musk to all parts of the room is some evidence of the fact that musk, a solid body, has particles which can escape. It possesses the property of divisibility.

Demonstration of Free Space Between the Particles Forming a Solid Body

(a) In Fig. 6 is shown a bell jar *J* on a base and from this bell jar the air can be exhausted. At the top of the bell jar is a wooden stopper which fits closely into the bell jar with soft wax. This wooden stopper is turned out with a small cup at the top in which mercury may be placed. On exhausting the air from the jar, the excess pressure

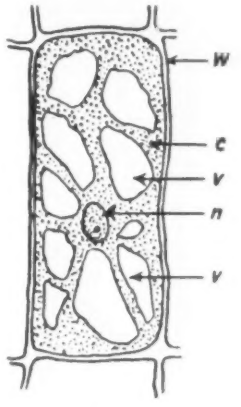


Fig. 7. This shows the cellular structure of wood as revealed under the microscope. (Courtesy *American Journal of Botany.*)

on the top of the mercury drives it through the wooden stopper and a rain of fine particles of mercury may be caught in a dish below the stopper. Fig. 7* shows a microscopic study of the structure of wood and this confirms our idea of the *porosity* of solid matter like wood.

*O. L. Sponsler. The Molecular Structure of the Cell Walls of Fibers. *American Journal of Botany*, Vol. 15, 1928, pages 525-536.

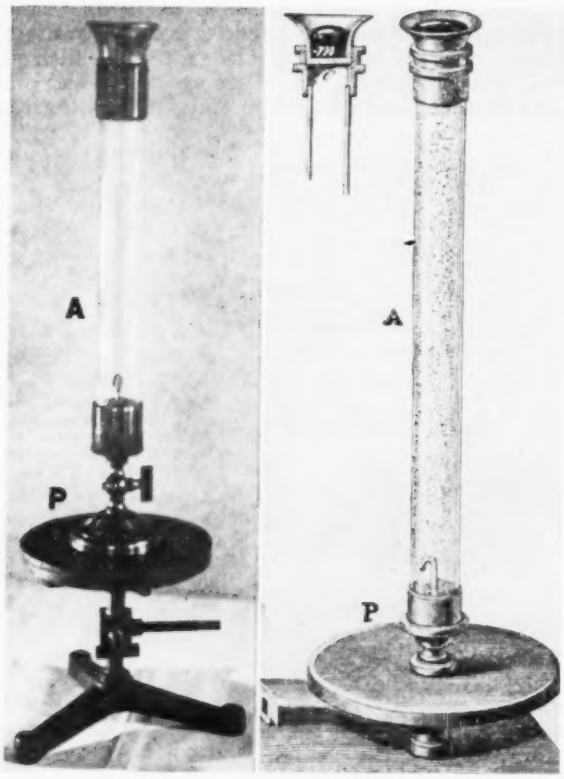


Fig. 8. Outfit for showing the porosity of leather.

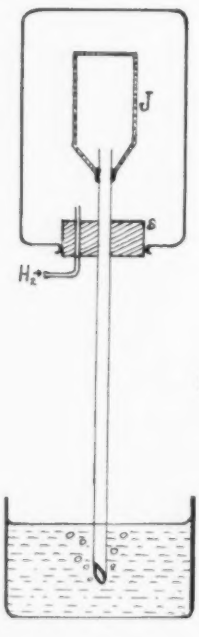


Fig. 9. Diffusion of a gas (H_2) through a porous jar, J.

(b) Fig. 8 is another similar device for showing *porosity* as a universal property of all states of matter. The jar in Fig. 8 has a piece of leather clamped in tightly at the point *p* and which forms the bottom to a small cup in which mercury may be placed. On exhausting the air below the leather, mercury begins to pour through in small droplets.

Is steel porous? Back in 1661 there was performed by the academicians of Florence, Italy, an experiment in which a thin-walled hollow sphere of gold was filled with water. When the sphere was pressed between the jaws of a machine the water was forced out through the pores of the gold and stood like dew on the outside of the sphere. Similar experiments have been tried with other metals and like results have been obtained. In the case of steel, gas can be forced through, showing that it also is porous.

(c) Diffusion of a gas through a porous jar.—A porous jar, *J*, Fig. 9, is sealed on to the upper end of a glass tube. The latter passes downward through a large stopper *S* which seals off a glass jar in which the porous jar is placed. Through the large stopper another glass tube is passed by which a gas like hydrogen (H_2) may be admitted into the glass jar so as to surround the porous jar. The smaller hydrogen molecules pass through the pores of the inner jar more rapidly than those of air within pass out, so that a pressure is built up within the porous jar which causes the gas to bubble out through the water at the bottom of the tube. The inner jar is a solid, nevertheless it exhibits porosity.

Porosity of matter gives rise to another general property of matter called *compressibility*. In fact, the compressibility of matter argues for the property of porosity, if by compressibility we mean the bringing of the particles of the substance closer together.

We are all aware of the compressibility of a gas when we blow up a tire, but can a liquid or a solid be compressed? The answer is yes.

Demonstration of the Compressibility of a Gas and of a Liquid

In Fig. 10 is a device known as a piezometer. It is a rugged glass cylinder closed at the top by a piston moved by a screw. A small funnel *R* at the top and closed by a stopcock is used for filling the glass cylinder with water,

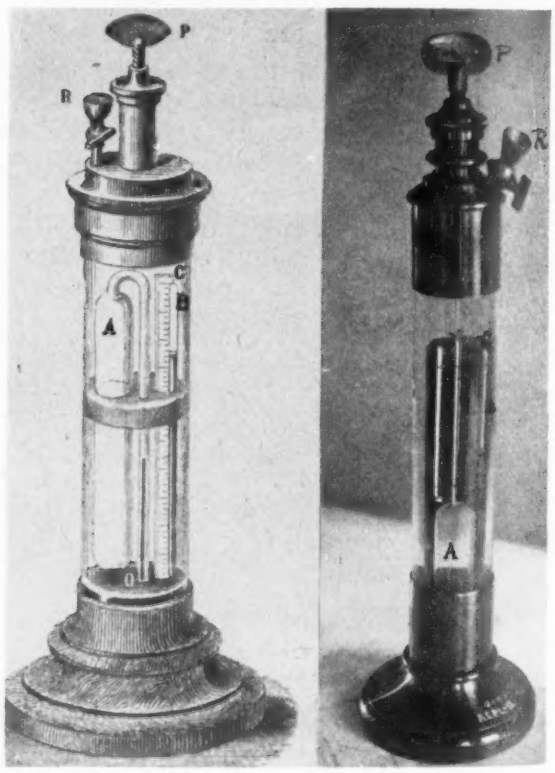


Fig. 10. A piezometer for showing the compressibility of gases and liquids. P is a screw piston for producing a pressure.

when all the parts have been assembled inside. These gadgets consist of a glass vessel *A* containing the liquid to be compressed. The upper part of *A* is sealed on to a capillary, which in turn is bent downward in a curve so that its lower end dips in a small pool of mercury at the bottom of the piezometer proper. Alongside of *A* is an inverted glass tube, *B*, sealed off at the top. Its lower end also dips in the pool of mercury. When no pressure is on the water surrounding *A* and *B* the volume of the tube *B* is completely filled with air. Inasmuch as the volume of tube *B* is known and a thermometer is also inclosed, the pressure applied to the piezometer may be determined by an application of Boyle's law. Furthermore, since the volume of the large

chamber of A is known, and the volume of the capillary tube is marked on its sides, it becomes possible to determine the compressibility of the liquid in tube A.

Thus far our arguments have gone to prove that solids, liquids and gases are composed of particles of matter, and that there is considerable space between those particles even in solids. Our demonstrations have shown that these particles in the case of gases and liquids are in a state of ceaseless agitation (which we will later describe as thermal agitation) and, therefore, assume that in the case of solids the particles composing them are also in a state of thermal agitation about fixed centers. In gases and liquids, the particles travel around from one point to another, that is, they diffuse. See Figs. 3 and 5. Although we think of the particles of a solid as simply oscillating about fixed points, we now have good evidence to show that even in solids this diffusion is going on slowly. Thus a clean surface of a block of silver, when brought into contact with a similar surface of gold, will show in the process of time that silver particles have diffused into the block of gold and, vice versa, gold particles have traveled into the silver block. This could only happen for solid media possessing interstitial space.

There are other physical properties of solid matter, which have a bearing upon this same problem of free space in solid materials. The property of *ductility* is that property whereby a solid can be drawn out into wire form. Allied to this is the property of *malleability* which permits a solid to be hammered into various forms without shattering.

Finally, one property which physicists seldom talk about is *hardness*. As a working definition, hardness is defined as resistance to penetration or resistance to permanent de-

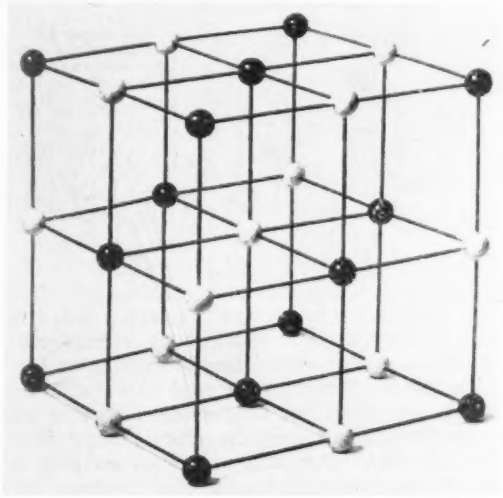


Fig. 11. The way in which the atoms of sodium and chlorine are arranged in a salt crystal.

formation. Hardness brings out more than any other property of solid matter that most interesting question, What holds the particles of a solid together so that they resist being separated when penetration occurs? We say there are cohesive forces when the particles held together are alike and adhesive forces when the particles are unlike. Thus a stamp and the glue by which it is attached is a case of adhesion. If we go no farther, cohesion and adhesion are simply words for covering up our ignorance of the forces which hold solid matter together.

However, we seem to be at the threshold of a large field of investigation which is going to throw much light on this subject. Pauling's book on the Nature of the Chemical Bond is an example in which we become more specific and refer to electrostatic bonds, covalent bonds and metallic bonds as the forces which hold things together. Fajans emphasizes the electrostatic bonds as the principal ones if one takes into account the distribution of ions and the nuclei in terms of movements of the ions. To say, however, just how these chemical bonds play into the measurement of hardness is going quite beyond our present knowledge of these matters.

Modern X-ray analysis has helped greatly in a better understanding of these forces which hold things together. Most solid matter is crystalline in its structure and it is to X-ray analysis that we owe our knowledge of how the particles are arranged. Thus in Fig. 11 is shown the way the sodium and chlorine atoms are arranged in a crystal of ordinary table salt. The white spheres may represent the sodium atoms and the black spheres the chlorine. In this model we are speaking of atoms as being the particles which are held together as we will in all crystalline structures. In the illustration shown in Fig. 11, the atoms are arranged in a cubic formation and the idea of a molecule of NaCl in the solid form has no meaning because we can't say what sodium atom goes with a certain chlorine atom. In the sodium chloride crystal with its atomic arrangement as shown in Fig. 11 it is composed of sodium cations, Na^+, and chlorine anions, Cl^-, each of which is strongly attracted to and held by the six oppositely-charged ions

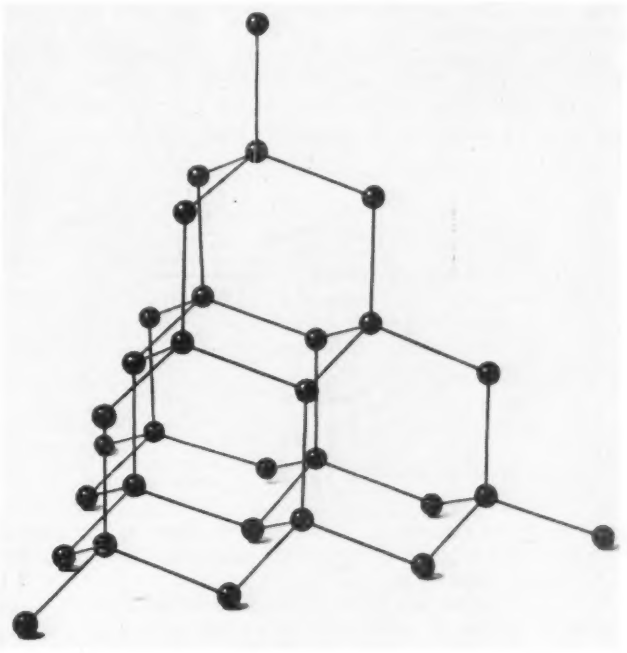


Fig. 12. The way in which the atoms of carbon are arranged in a diamond.

which surround it octahedrally. The interactions in a crystal of salt may be described by saying that each ion forms ionic bonds with its six neighbors, these bonds combining all of the ions in the crystal into one giant molecule.

The diamond is the hardest of all substances. Why is it so hard? Because of the powerful covalent bonds existing between the atoms of carbon composing the diamond. This type of bond involves the sharing of a pair of electrons by the two bonded atoms. Fig. 12 shows the arrangement of the atom of carbon in a diamond crystal. Diamond is hard or resists penetration because of these covalent bonds and, since these forces follow the inverse square law, the short distances between centers of the small carbon atoms add to the effectiveness of these covalent bonds.

When we come to the metallic bonds we have quite a different case. Here we have great mobility to the bonding electrons. Take copper for example; the one valence electron must be first on one side of the atom and then on the other—pulsating, as it were, between atoms. These mobile electrons are, of course, what make copper, silver, gold, etc., such good conductors of electricity and heat; but with such high mobility there can be no great rigidity of formation. These substances are noted for their plasticity, malleability and ductility.

When we come to magnetic properties later on we shall be greatly interested in the ferromagnetic bodies like iron, nickel, cobalt and their alloys.

(Continued on page 220)

ELECTRON TUBES—Their Principles and Their Instrumentation Applications

By ANDREW W. KRAMER, Managing Editor, Power Plant Engineering, Chicago, Ill.

CHAPTER XIII
THE PRINCIPLES AND CHARACTERISTICS OF THE TETRODE

Now that a few facts about the principle of neutralization of amplifier circuits have been explained, we can return to a consideration of the screen-grid tube. The principle of neutralization has been described because a knowledge of this principle helps in obtaining a better understanding of the function of the screen-grid tube. This method of approach is also better from a chronological standpoint since the screen-grid tube did not come into general use until some time after neutralized amplifiers had been used to a considerable extent.

Several factors contributed to the development of the screen-grid tube. These may be set forth as follows:

1. The limitation which prevents the effective use of the triode as an amplifier at extremely high frequencies is the inter-electrode capacitance of the tube. Simply, this means that the tube acts as a capacitor which couples the output to the input side of the circuit.

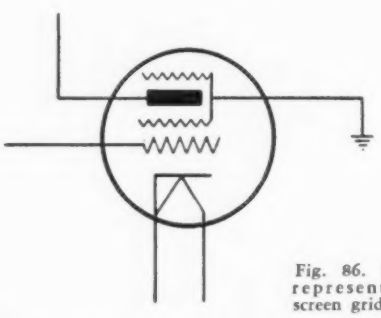


Fig. 86. Diagrammatic representation of the screen grid tube.

2. To overcome this limitation, neutralizing circuits were developed which, in effect, neutralize the capacitance of the tube, thus permitting stable amplifier operation even at high frequencies.

3. The neutralized amplifier, despite its advantages over un-neutralized circuits, obviously, is a makeshift affair and it was clearly apparent from the beginning that if a tube could be developed which would exhibit no capacity effect, neutralization would be unnecessary and circuits would be much simpler. This tube is the screen-grid tube.

Suppose that in an ordinary triode a second grid, made in the form of an electrostatic shield, is placed between the control grid and the plate as shown in Fig. 86, and suppose further that this second grid is grounded. Since this second grid entirely surrounds the plate it forms an "electrostatic shield" around the plate and prevents any fluctuation of plate potential from affecting the grid; in other words, it practically eliminates the capacity effect between the grid and the plate. It does not, however, prevent electrons from the cathode and under control of the control grid from reaching the plate. In practice the "screen" grid is not grounded directly as shown in Fig. 86, but this serves to illustrate the principle involved.

Quite obviously, it is not practical to entirely shield the plate by a screen of this kind since that would prevent the input voltage from reappearing in the plate circuit, but the screen can usually be made to reduce the capacity effect to a very low value—essentially to zero as far as "feed-back" is concerned. In triodes with grid plate capacitances of 2 to 8 mmf. the addition of the screen grid will result in capacitances of 0.1 to as low as 0.003 mmf.

The mechanical construction of the screen grid varies with different types of tubes. In the early tubes the screen grid consisted of two helical grids close to the plate, one inside and the other outside the plate and connected together. In later tubes in some instances the outer screen was dispensed with. Such tubes as generally used today are surrounded by a metal can which is grounded and this prevents fluctuations of the plate voltage from reaching the input circuit of the tube. A diagram of a screen grid tube in which the plate is entirely surrounded by the screen is shown in Fig. 87.

The screen grid is usually maintained at a positive potential somewhat lower than the plate potential by connecting it to a suitable point on the power supply, as shown in Fig. 88. It is therefore not at ground potential so far as the plate current is concerned but a by-pass capacitor is usually connected across the screen grid and ground connection so that the screen is at ground potential insofar as the high-frequency current is concerned. If the capacitance of the by-pass capacitor C in Fig. 88 is, say, of the order of 1 microfarad, the impedance between screen and ground will be less than 1/6 of one ohm; it is evident, therefore, that with such a low impedance to ground the screen potential cannot fluctuate with respect to ground. The screen-grid potential is usually about one-third less than that on the plate.

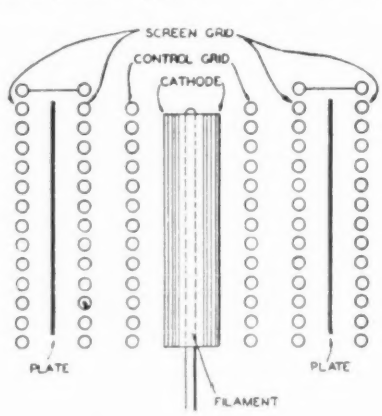


Fig. 87. Cross-section showing one arrangement of a screen grid tube. In this case the screen completely surrounds the plate.

Since the effect of the screen grid is to neutralize the capacity effect of the tube, it is evident that no neutralization is required in an amplifier circuit using screen-grid tubes. The circuits, therefore, are much simpler and are more suitable for operation over a wide frequency range.

While the neutralizing effect of the screen grid is of primary importance in high-frequency amplifier circuits, the screen grid exhibits another property which is of equal or perhaps even greater importance. By shielding the plate from the cathode, it makes the plate voltage much less effective in attracting electrons from the cathode without impairing the ability of the control grid in this respect. Consequently the grid is much more effective in changing the plate current than is the plate and, as a result, the amplification factor of the screen-grid tube is high. By the same token its plate resistance is also high. These terms, amplification factor and plate resistance, are discussed in a later chapter but it may be said here that these properties, high amplification factor and high plate resistance, are desirable in any tube; hence, the screen-grid tube is doubly effective.

From the foregoing it might be inferred that the introduction of the screen-grid into the electron tube, by eliminating the troubles due to feed-back, at once removes all limitations in the use of tubes as amplifiers. In this instance, however, as in many other cases of a similar nature, the solution of one problem introduces others of a different character. The extra grid, while a valuable ally in suppressing feed-back, is not entirely free from entangling alliances in other matters. Since the screen-grid is main-

tained at a positive potential, it attracts electrons and this, under certain conditions, causes difficulties.

Ordinarily, the electrons emitted by the cathode are accelerated toward the plate, just as in the simple triode. First they speed through the control grid and into the region of the positive screen grid. By this time they usually have acquired sufficient velocity to enable them to rush on through the screen grid field to the plate. The action of the control grid is exactly as it is in the triode. Most of the electrons which the screen grid attracts pass through its meshes and go on to the plate which is more positive, so that while the screen grid serves as an almost perfect electrostatic shield it intercepts only a relatively small portion of the total electron flow.

At certain times, however, under a-c. operation, the plate potential may be reduced to a value lower than that of the screen and then the electrons would not go on to the plate, but would stop at the screen, or having once got past the screen and close to the plate, they would turn about and return to the more positive screen. Furthermore, if an electron impinges upon the plate with sufficient velocity to knock another electron out of the plate, as is often the case, this electron will be drawn into the screen. This "splashing" out of electrons from the plate, by the impact of high-speed primary electrons, is known

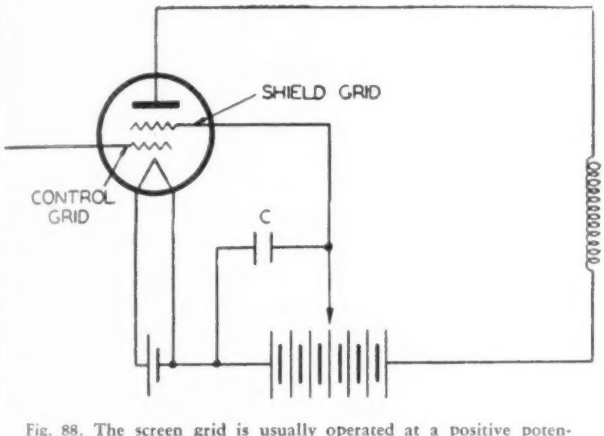


Fig. 88. The screen grid is usually operated at a positive potential, slightly lower than the plate potential, by connecting it to an intermediate point on the plate supply.

as secondary emission. When the plate is at the same or higher potential than the screen such secondary electrons are drawn back into the plate, but if the plate is at a lower potential than the screen all of the secondary electrons (and there will be countless millions of them) will be drawn to the screen.

The net result of this action is to produce a current from the plate to the screen. This entirely changes the characteristics of the screen-grid tube as compared with the usual triode. Referring to Fig. 89, which is the characteristic curve of a typical screen-grid tube with zero control grid voltage and a constant screen grid potential of 83 volts, it will be noted that at plate potentials appreciably lower than the screen grid voltage the plate current actually reverses. In the region from 0 to approximately 10 v. the plate current increases with an increase in plate voltage. Increasing the plate voltage further, however, results in a decrease in plate current and from about 30 to 70 v. the plate current actually reverses. The reason for the upward slope of the curve between 0 and 10 volts is due to the fact that at these low plate potentials the electrons are unable to acquire sufficient speed to cause secondary emission from the plate. At slightly greater plate potentials, from 10 to around 83, there is secondary emission and the plate loses secondary electrons to the screen. Beyond 83 volts, the plate is at a higher potential than the screen and as a consequence it is able to capture more and more of the secondary electrons as the plate voltage increases. In the region where the plate current is negative, for each primary electron that reaches the plate, more than one secondary electron is lost to the screen grid.

The proceas of secondary emission at the plate is one that closely resembles the process of ionization described in an earlier chapter.* The high-speed electrons from the cathode act as projectiles and their impact upon the material of which the plate is made is such that free electrons and electrons belonging to atoms of the plate material are smashed out of the plate. If the speed of the primary electrons is low, only one secondary electron may be driven out of the plate, but if the speed is higher, two, three, or even more secondary electrons may be released with each impact.

From this it is evident why the plate current actually reverses under certain ratios of screen grid to plate voltages. This action of secondary emission is of course also present in ordinary triodes, but in triodes the secondary electrons are all drawn back into the plate. In the screen-grid tube, however, they can either go to the screen grid or to the plate and if the potential of the former happens to be higher or at approximately the same potential as the plate they will go to the screen. Only by making the plate potential sufficiently higher than the screen potential can all of the secondary electrons be recaptured by the plate.

Although the characteristics of the screen-grid tube, as shown by Fig. 89, appear rather complicated as compared to the characteristics of a triode, they depend upon a rela-

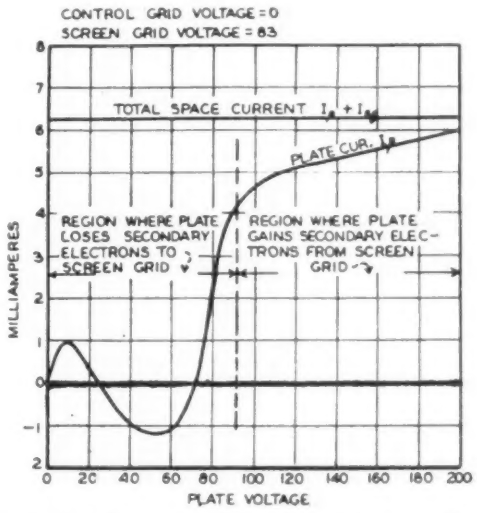


Fig. 89. Typical plate current characteristic of a screen grid tube.

tively small number of factors. The primary electrons travel in substantially straight lines away from the cathode and therefore divide between the screen grid and the plate in proportion to the projected areas of the screen grid and plate structures. The result is that for any particular tube each electrode will always receive the same fraction of the primary electrons irrespective of the cathode voltage or the total space current. The number of primary electrons received by an electrode, therefore, is proportional to the total space current.

The number of secondary electrons produced both at the screen grid (for secondary electrons are also produced by impact of primary electrons on the grid) and at the plate is proportional to the number of primary electrons received by the electrode and also, roughly, to the electrode potential. The subsequent flow of these secondary electrons is then determined by the screen-grid and plate potentials.

When the screen grid is appreciably more positive than the plate, practically all of the secondary electrons produced will be drawn to the screen grid. When the plate is more positive than the screen grid, however, only a part of the secondary electrons produced at the screen grid are drawn to the plate. This is due to the fact that most of the screen-grid secondary electrons are produced on the side of the screen grid that is away from the plate and so are partly shielded from the attraction of the plate by the screen grid. When the plate is the most positive electrode it is, therefore, able to attract only a portion of the secondary electrons from the screen grid, this proportion be-

*Chapter VI, Oct. 1943 *Instruments*.

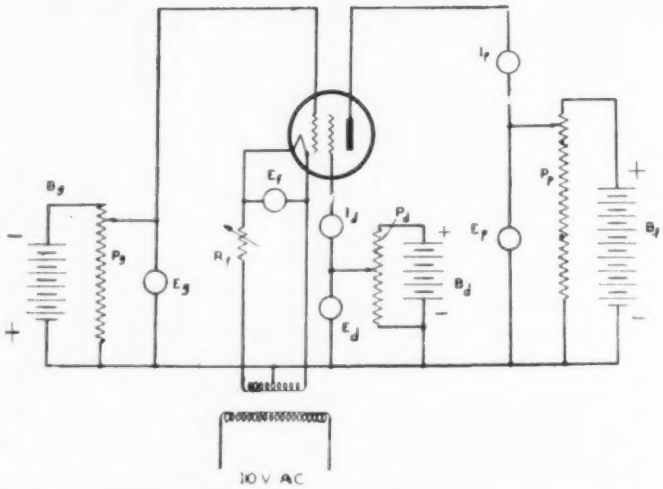


Fig. 90. Circuit diagram for determining the volt-ampere characteristics of a four-electrode or screen grid tube.
P_g = Grid circuit potentiometer (2500 ohms, 0.3 amp.)
B_g = Grid battery (60 v.)
E_g = Grid voltmeter (0 to 50 v. d.c.)
E_f = Filament voltmeter (0 to 10 v. a.c.)
R_f = Filament rheostat (6 ohms, 5 amp.)
I_p = Plate ammeter (0 to 100 ma., d.c.)
B_p = Plate battery (0 to 400 v.)
P_p = Plate circuit potential-dividing resistor (6400 ohms, 0.3 amp.)
E_p = Plate voltmeter (0 to 500 v., d.c.)
I_d = Screen-grid ammeter (0 to 10 ma., d.c.)
E_d = Screen-grid voltmeter (0 to 250 v., d.c.)
E_d = Screen-grid battery (0 to 180 v.)
P_d = Potential-dividing resistor (2500 ohms, 0.3 amp.)

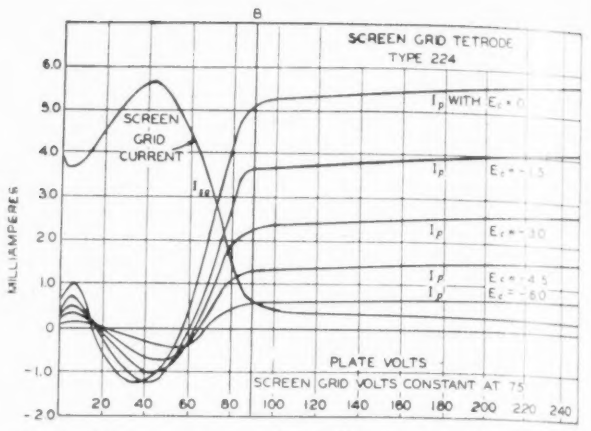


Fig. 91. Plate current curves of an ordinary screen grid tetrode.

coming larger as the potential of the plate with respect to the screen grid is increased. The results of these factors are (1) that with given screen-grid and plate potentials the ratio which the current received by either electrode bears to the total space current is roughly constant irrespective of the total space current, but (2) that the fraction of the total space current received in any particular case depends greatly upon the relative (and also the absolute) electrode potentials.

These relations need not necessarily be remembered but a knowledge of them will aid in forming a clear concept of the action of the screen-grid tube.

As in the case of the triode, a comparatively simple circuit may be set up for studying and determining the characteristics of the screen-grid tube directly. Such a circuit is shown in Fig. 90. This circuit, as will be seen, contains all the necessary batteries, voltage-dividing resistors and indicators for varying and measuring the potentials and currents in the circuit under various conditions. The filament is supplied with alternating current through a small step-down transformer. Three batteries are provided: B_g for applying voltage to the control grid; B_d for applying voltage to the screen grid; B_p for furnishing potential to the plate. The voltage from each of these batteries is controlled by voltage-dividing resistors. For any particular tube, the filament voltage should be held constant.*

By means of such a circuit it is possible to obtain a series of curves such as shown in Fig. 91: the plate current curves under various conditions of control grid voltage but with a constant screen grid voltage. Another set of curves can be obtained by varying the screed grid and plate voltages. Such a family of curves is shown in Fig. 92. These appear complicated but when examined will be found only little more complicated than a family of curves for an ordinary triode. They are presented here not so much to be studied as to familiarize the reader with their appearance, so that if he ever finds it necessary to determine the suitability of certain tubes for certain purposes he will not be discouraged by the formidable appearance of the tubes and of the tube curves.

Fundamentally, it will be obvious, the addition of the screen grid does not alter the triode's primary function—that of amplification. The screen-grid tube is an amplifier just as is the triode but with certain limitations of the triode removed. The phenomenon of secondary emission, it is true, introduces new difficulties—at least under certain conditions of voltage—but these can be anticipated and in some cases it has actually been put to good use. In the next chapter we shall see how even the wasted part of the screen-grid tube characteristic can be reclaimed.

*For detailed directions in setting up this circuit and making the necessary measurements, the reader is referred to "Experimental Electronics," a booklet of laboratory experiments on electron-tube theory published by the General Electric Co.

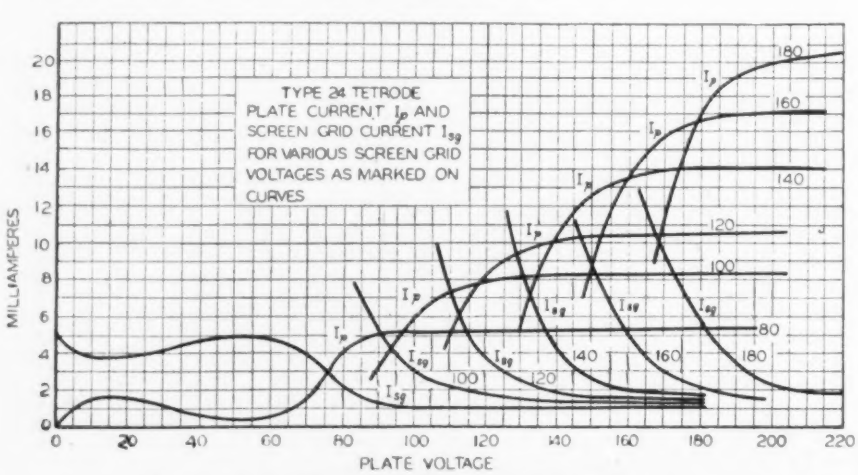


Fig. 92. Characteristics of the ordinary screen grid tube operated over a wide range of screen and plate voltages.

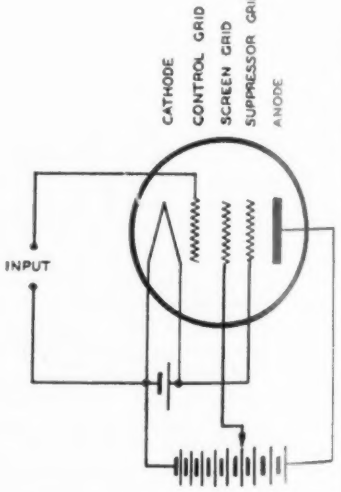


Fig. 93. This is how the five elements in the pentode are usually disposed and connected in the circuit. The connection between the suppressor grid and the cathode is often made within the tube itself.

CHAPTER XIV

THE PENTODE. THE PRINCIPLE OF THE SUPPRESSOR GRID

Next in the order of increasing complexity in our study of tubes is the pentode or five-element tube. Many five-element combinations are possible but the only one that is used to an appreciable extent is the cathode-grid (or suppressor grid) pentode, developed to overcome the secondary emission effect of the tetrode. This is a tube with three grids.

This third grid is placed between the screen grid and the plate as indicated in Fig. 93 and its function is to prevent the secondary electrons from reaching the screen grid. It is, therefore, called the suppressor grid. It is connected directly to the cathode or to a point of zero potential and because of its low potential repels the relatively-low-velocity secondary electrons back into the plate without appreciably obstructing the primary electrons speeding from the cathode to the plate. As a consequence, with a tube of this

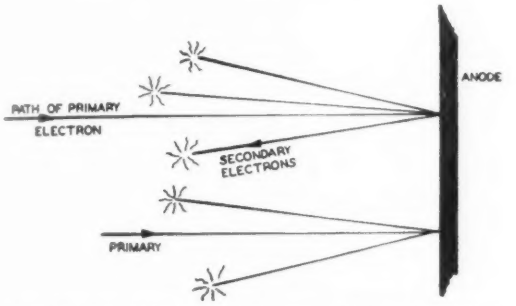


Fig. 94. Diagram showing the principle of secondary emission. High-speed primary electrons impinge upon the plate with such force as to dislodge electrons from atoms of the plate material and knock them out into space. Here, two primary electrons produce five secondary electrons. The number of secondary electrons produced is dependent upon the speed (and therefore the energy) of the primary electrons.

kind the so-called negative-resistance region* of the screen-grid tetrode is eliminated. This tube has approximately the characteristics of the screen-grid tube without its limiting features. Large undistorted power outputs can be secured from the pentode. The connection between the suppressor grid and the cathode is usually permanently made within the tube structure.

The principle of secondary emission is illustrated in Fig. 94 and its action in the three types of tubes (the triode, the tetrode and the pentode) in Figs. 95, 96 and 97. Secondary emission is the result of impact of high-velocity electrons or ions with the atoms and electrons of a solid body such as the plate of an electron tube. The speed with which the impinging electron must strike the metallic surface to get secondary emission depends upon the material and the condition of the surface of the anode. Thus, tungsten with a clean surface requires the speed acquired by an electron falling through 180 volts before another electron is splashed out, but if there is a layer of gas covering the tungsten (adsorbed gas) secondary electrons may be given off by the impact of an electron falling through only 30 volts. At comparatively low velocities of the impinging electron only one electron may be splashed out of the anode but as the velocity increases, more than one may result. In extreme instances as many as a dozen may be splashed out.

In the absence of other influences, such secondary electrons will at once re-enter the surface from which they have been emitted, particularly if they are projected into the range of a negative field such as that of a negatively-charged control grid. This is shown in Fig. 95. Here an electrostatic field exists between the control grid and the anode as indicated by the (dotted) lines of force.

If however, a positively charged grid such as the screen grid of Fig. 96 is placed between the plate and the control grid, some of the lines of force from the control grid, instead of terminating on the plate, will terminate on the screen grid since that is at positive potential with respect to the control grid. As will be noted, this removes (so to speak) some of the lines of force from the space adjacent to the plate. Hence secondary electrons are not driven back to the plate so quickly and if they come too near the screen, they will be attracted to the screen and absorbed in it. Thus, the presence of the screen grid results in an electron current away from the plate. *(Continued on page 224)*

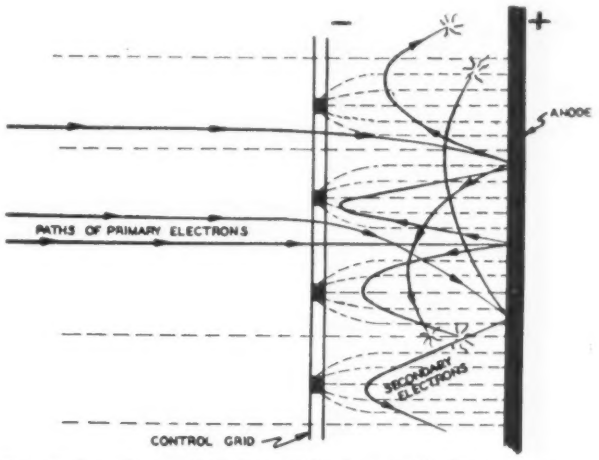


Fig. 95. Secondary emission in a triode. In a triode the secondary electrons are driven back into the plate by the negative charge on the control grid.

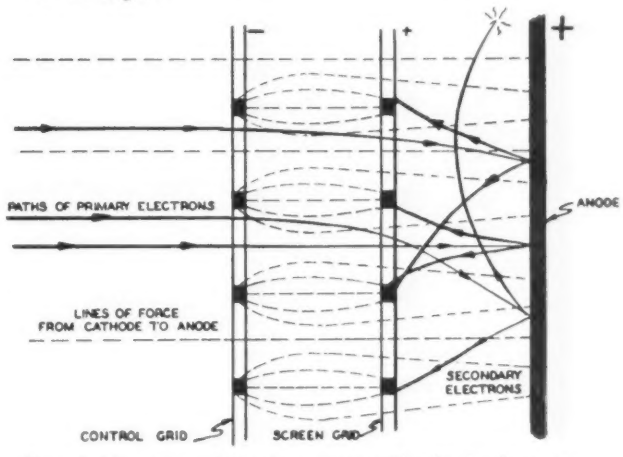


Fig. 96. Secondary emission in a screen grid tube. In the screen grid tube, the positively charged screen grid neutralizes a part of the negative influence of the control grid, thus attracting the secondary electrons originating at the plate.

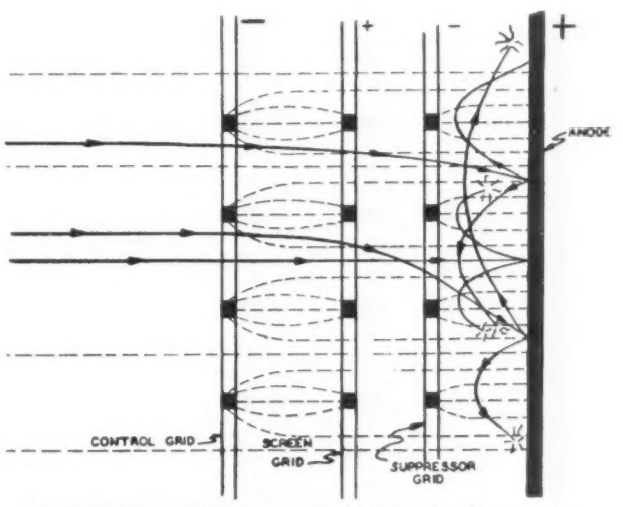


Fig. 97. In the pentode a suppressor grid is introduced between the screen grid and the plate. When this suppressor is connected to a point of zero potential with respect to the cathode, this grid suppresses the influence of the screen grid by re-establishing a negative field close to the plate.

*That part of the plate current characteristic where the plate current decreases with an increase in plate voltage or in general, that portion of the curve where the plate potential is less than the screen grid potential.

APPLICATIONS OPERATING PRINCIPLES INSTALLATION MAINTENANCE

Aviation Instruments

Navigation Automatic-piloting Power plant Automatic-landing Aerological
Communication Flight-testing Production Instrument-testing

Vol. III, No. 4 M. F. Behar, Editor April 1944

Synchronous Tac Tester

By M. J. WIGGINS (A.M.M. 1c1, USNR) Vero Beach, Fla.

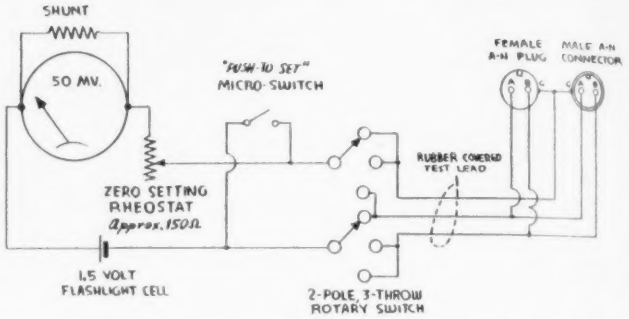
THIS little gadget has proved a time saver in checking synchronous tachometer installations. Its purpose is to check the electrical condition of the generator, leads and indicator, by connecting into the circuit at the indicator—which is usually easily done. Inasmuch as the generator is simple, mechanically, most of the troubles on that end will be electrical. If the electric circuit of the generator is OK, the indicator will probably be at fault.

The principle of operation of the test unit is as follows:

The generator is a three-phase type, each phase having the same resistance. The millivoltmeter on the test unit is calibrated for each make of generator in use; the Kollsman, Pioneer and General Electric, as each make has a different resistance value. By disconnecting the plug from the indicator of a faulty installation and connecting the plug to the male connector on the test lead, the millivoltmeter needle should swing to one of the generator marks, depending on the make of generator. Turning the switch to the other two points will give a check on those phases. Before taking the above readings the millivoltmeter must be set to zero by depressing the "Set" button and adjusting the rheostat. If any of the readings are different, then there is trouble in the odd phase. If one of the phases checks bad through the leads, the test unit should be plugged into the generator itself to determine whether the trouble is in the wiring or the generator.

The indicator can be tested electrically by plugging into the test unit female plug. The millivoltmeter dial is laid off to correspond with the three makes of indicators.

The unit pictured is built in a "first aid kit" box. The

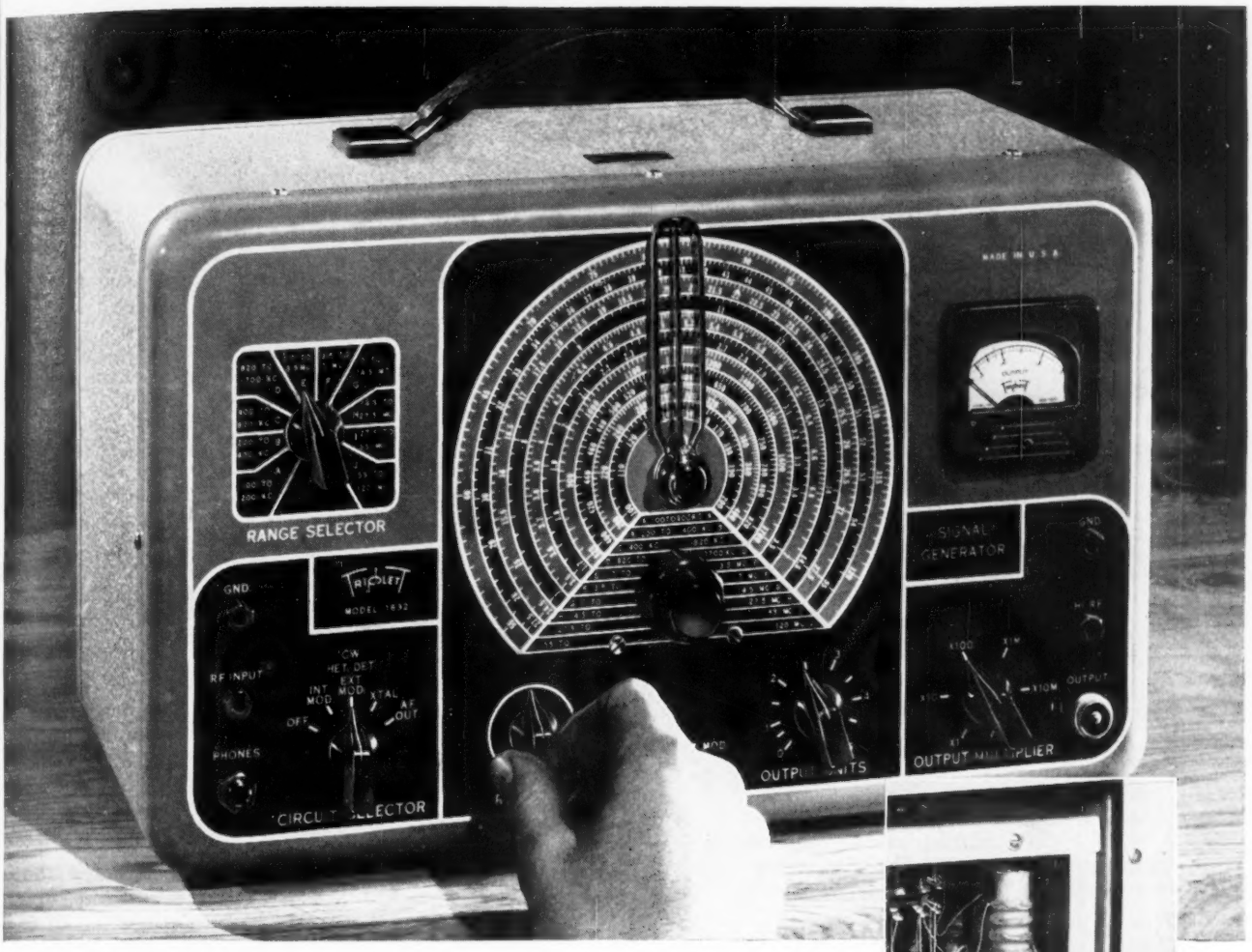


millivoltmeter is a salvaged ammeter, recalibrated as shown. To calibrate a similar instrument, the shunts or external resistors should first be removed. A blank dial is drawn and mounted in the instrument. If the instrument case has no iron shielding it may be left off during calibration; otherwise the glass should be removed so that the dial may be marked. Connect up the various parts as shown in the circuit diagram with the exception of the shunt. Set the millivoltmeter to zero by closing the microswitch and adjusting the rheostat. Connect the plug to selected generators and indicators of each make which are known to be correct, and mark with pencil the point to which each one brings the pointer. It will be noted that the marks are all crowded at the far end of the scale. To spread the marks for easier reading, a shunt of 2 or 3 ohms should be connected across the millivoltmeter terminals. The foregoing procedure for marking is repeated and the shunt resistance varied until the desired spread is obtained. When the marks are properly located, they should be inked in, using black ink for the generators and red ink for the indicators. The unit may now be assembled permanently.

Only one plug on the test lead shows in the photograph; however, two connector plugs are wired in parallel as seen in the diagram.

Electronic Robots Read Motor Speeds in Wind-tunnel Tests

ELECTRONIC robots that read instruments far more accurately than a man can, and which print their readings on a strip of paper (like print-weight scales or cash registers) are used to measure with high precision the speed of motors used in airplane wind tunnel tests, according to Everett S. Lee, engineer in charge of the General Engineering Laboratory of the General Electric Company, speaking before the Akron Section of the American Institute of Electrical Engineers. Wind-tunnel models, he explained, are powered with small electric motors. In order that information about the performance of these motors may be extended accurately to the big airplanes, data about their operation must be determined with great precision. The indications picked up by electron tubes, he explained, cause the rotation of a tiny thyratron-controlled motor,



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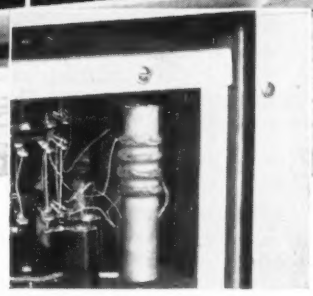
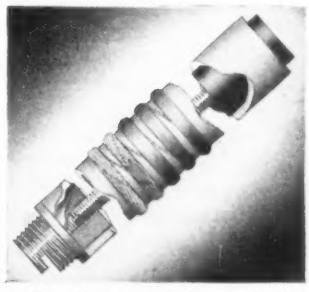
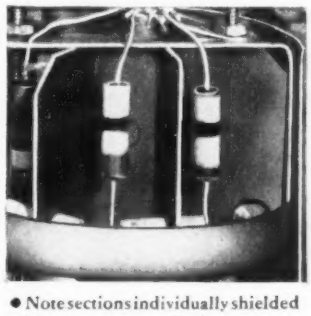
Of course today's production of this and other models go for war needs, but you will find the complete Triplett line the answer to your problems when you add to your post-war equipment.



• Triple shielding throughout, Steel outer case, steel inner case, plus copper plating.



• All coils permeability tuned. Litz wire wound impregnated against humidity with "high-Q" cement.



• Note sections individually shielded with pure copper. Entire unit encased in aluminum shield.

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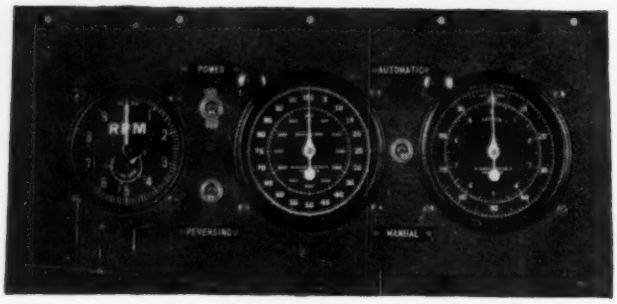
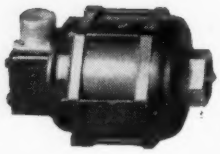
CHRONO-TACHOMETERS



. . . and their contribution to instrumentation.



For several years our chrono-tachometers have been recognized and used by Aircraft Engine Manufacturers as the most accurate and most dependable instruments for precise speed measurements to determine fuel consumption, oil consumption and developed horsepower.

The method of obtaining precise speed measurements, that of employing a clutch type revolution counter, connected in multiple with a clutch type stop clock for simultaneous operation, early established its superior accuracy, convenience and reliability.

Constant attention and effort have been devoted to improvements. One of the first and most valuable was the development of electric drive whereby self-synchronous motors, or a self-exciting three-phase alternator and synchronous motors, are used instead of flexible shafts.

Another addition was the rapid speed check which obtains an accurate count of revolutions for an exact 1/10 of a minute.

The problem of maintaining clockwise rotation of tachometer and revolution counter hands has been solved by development of an automatic reversing mechanism for flexible shaft drives, and by control switch operation for electric drives.

For those users to whom an extra large tachometer dial is important, a dial 6″ in diameter is available.

The additional feature on which we are now working and which will be an integral part of the chrono-tachometer is an overspeed cutout to operate automatically to shut off an engine when it exceeds a certain speed, and thereby prevent it from running away.

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which in turn drives wheels carrying type for numbers. When the operator wants to take a reading he presses a button, and the type wheels print their setting at that moment. Mr. Lee explained that the mechanisms may be adjused to give the equivalent of readings on a scale more than eight feet long.

Questions on Altitude Compensation

Aviation Instruments Dep't of *Instruments:*

We'd like to have you settle a problem which has been puzzling a few of us. It concerns altitude error in the rate-of-climb.

In an instrument having a long capillary tube as the leak, we know that the readings will become "faster" with increasing altitude, i.e., the indicated rate will be more than the actual rate.We have partly explained this to ourselves by the following points:

A. When a leak occurs through a long capillary tube, the pressure drop is practically independent of the density.
B. Thus the rate-of-leak would be constant for all altitudes.
C. The rate-of-leak would be too slow at high altitudes, causing the differential pressure to be too great, giving us a "fast" reading.

But, here viscosity rears its ugly head. Viscosity changes both with a change in temperature, and with a change in altitude-pressure and density. These are our questions:

1. Does viscosity have a great influence on altitude error, and just what is the effect?
2. Is compensation for change in viscosity known as altitude or temperature compensation?
3. How is viscosity expressed numerically in the theoretical equation for the rate-of-climb?
4. Will porcelain diffuse a lesser or greater amount of air when the viscosity becomes less?

Thanks a lot for any information you can give us!

WILLIAM L. JACKSON
Instrument Mechanic
Pan American Airways

Boeing Field,
Seattle, Wash'n

Referred to the Aircraft Instrument Guild's Q&A Dep't

Thermostats "Promoted" from Household Duties to Airplane Service

SERVING now as a sky fireman ready to help put out blazes in Uncle Sam's warplanes is the little metal disk that used to control the temperature of electric irons. Thousands of thermostats the size of half dollars are being produced for "fire patrol in airplanes" at the Mansfield (Ohio) Westinghouse plant. Attached to motors and at other strategic parts of combat planes, the thermostats operate on a principle entirely different from that of automatic sprinkler systems used in factories. Sprinklers have fusible links that melt, thereby releasing the water, and cannot be used again. Furthermore, a sprinkler in itself is not a signaling device. In a warplane, the tiny bimetal disk does not release carbon dioxide but at a certain temperature it makes two tiny silver contacts close an electric circuit, causing a light to flash on the pilot's dashboard. Then, the pilot if the high temperature results from a fire caused by a tracer bullet, a leaking gas tank or an overheated motor, the pilot knows, from the location of the signal light, which lever to pull to release carbon dioxide and put out the fire.

Thermostats have various other wartime aviation applications, according to Westinghouse news notes. Keeping oil in a fluid condition in the gear case of aerial cameras on mapping missions in frigid temperatures is a problem solved by a small cartridge type heater with a one-inch thermostat control. The oil-bathed gear is necessary to keep the camera level despite flight variations.

Radio equipment aboard planes is prevented from freez-

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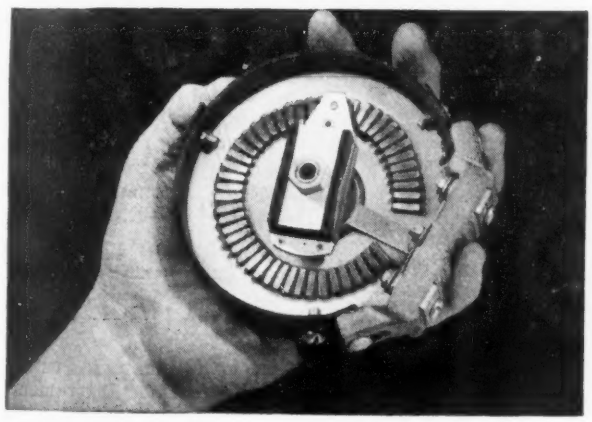

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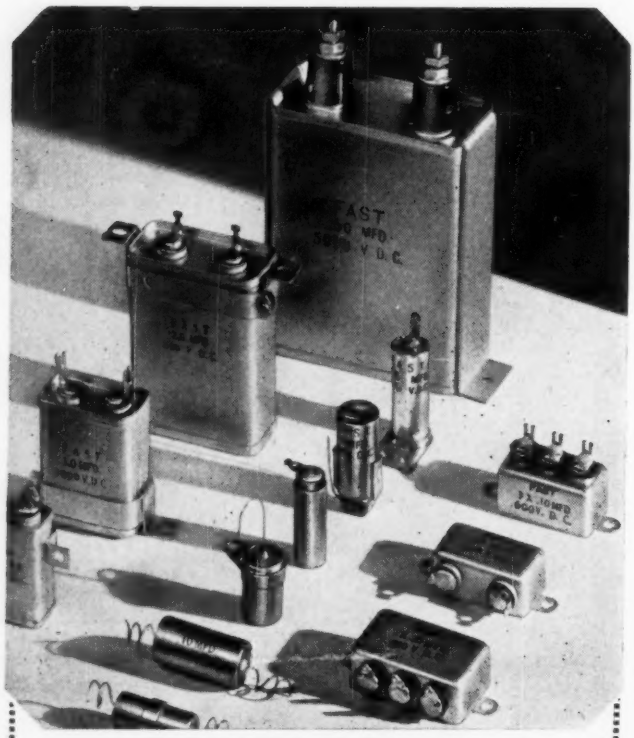

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AIRCRAFT INSTRUMENT GUILD

INTERNATIONAL HEADQUARTERS

812 N. DELAWARE PLACE
TULSA, OKLAHOMA

The following articles have been contributed by the Aircraft Instrument Guild. For further information on any of the subjects discussed, write to the Guild at the above address.

From the Guild President

ON our recent trip to Washington, New York, Cleveland, Jacksonville, Pensacola, Corpus Christi and Atlanta, we heard criticisms of our proposed classification of Aircraft Instrument Mechanics; so, hereafter, each Guild member will be known as a "Member" until such time as the CAA issues him a bonafide rating after he has passed the necessary examination.

At long last the gold-stamped leather identification cases arrived. They were mailed out to all members; but some were returned by the Post Office for want of forwarding addresses. *Please* help us keep our addresses up-to-date!

The Sperry Gyroscope Co. sent us 300 lbs. of factory information. This will be sent out to all Guild members. I'm sure that other aircraft instrument factories will follow suit before long.

Does every member know all about instrument overhaul, maintenance, installation, trouble-sheeting, etc.? Of course not! Then, send questions for the Guild's Questions-and-Answers Column.

A number of requests for information or organizing local chapters of the Guild have been received and answered. We hope that more local chapters will be organized, because this is the best way in the world to advance the Guild's program as an educational organization, to unify all of us and to hasten recognition by the Civil Aeronautics Administration. —R. G. OJERS.

Calibration of the Sperry Turn Indicator or Directional Gyro

By GERALD E. McEWEN, Ass't Foreman Instrument Repair, Brookley Field; Instructor Gyroscopic Instruments.

IN order for every one to thoroughly understand just what I'm talking about when I speak of "Turn Indicator," I will endeavor to explain the difference of identification. In order for us to keep all of our work order records straight, the Army has made a distinction between the Turn Indicator (the flight instrument) and the Directional Gyro (the Directional control unit of the Automatic Pilot). Now when I speak of a Turn Indicator I have no reference to the Pioneer Bank and Turn Indicator.

Arguments have raged among Gyro mechanics in regards to calibration. That's probably why so few articles have been written about this step in overhaul. To write an article that everyone would agree upon would be next to impossible. In this article I shall jot down a few things that may be helpful to any of you that have been having trouble calibrating your Turn Indicator. I have tried to coördinate my work in steps, so as to keep from repeating any procedures, thus saving time that would be charged up against my instrument and thereby getting out more production. In this day and age we all have to do all that is in our power to step up production.

IRC will be Ready

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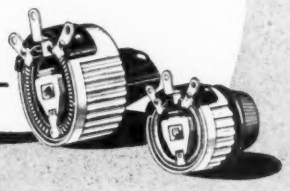

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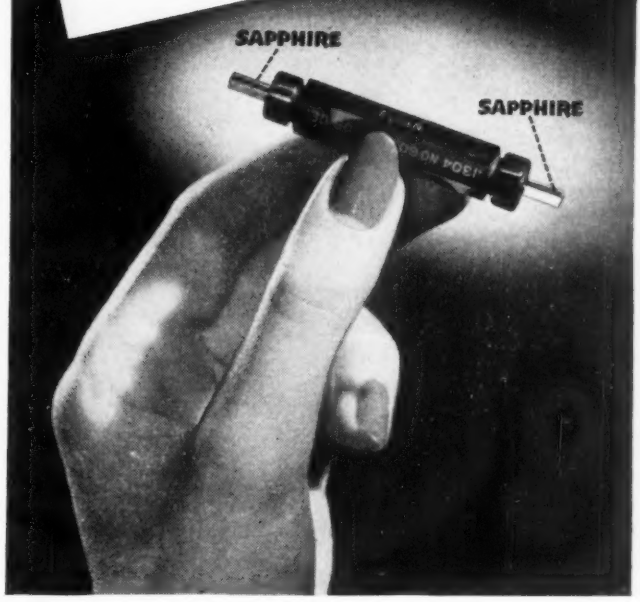

FOR dependable accuracy and long-life economy, nothing can match the Go and No-Go sapphire plug gages now available from Elgin.

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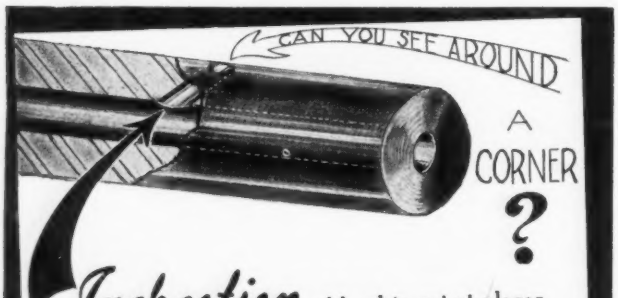

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To begin with, we all will agree that we should have our Instrument as nearly perfect as possible in order to calibrate it. We know that a Gyroscope has two fundamental principles of operation, Rigidity and Precession. Rigidity is that physical property of a spinning mass to remain rigid, or in the same position, in space until some outside force acts upon it. Precession is the physical property of this spinning mass to change its position at ninety-degree angle to the direction in which this outside force is applied. A few people think of this when they are trying to calibrate their instrument, but if it were possible to set up a frictionless bearing your turn rotor would remain in the same position in space indefinitely until some outside force would act upon it. Thus in every revolution of the earth, to one standing here looking at this rotor it would seem to completely turn over one revolution, or to precess completely 360 degrees.

This cannot happen in our turn indicator because if the rotor would precess more than 55 degrees off the vertical the gimbal would touch the vertical ring and the precession would revert to the vertical ring and the card would spin. Now another reason that this does not happen is that the force of the air out of the air nozzle will keep this rotor from tilting and will hold it on a level position. In doing this we are making this rotor or free gyro precess 360 degrees every 24 hours, in reference to space. Now when we make this rotor precess like this and the air nozzle is holding it level, then this force is removed from the gimbal and placed upon the vertical ring and card, thereby making the instrument precess off the heading. This precession will amount to approximately 3 or 4 degrees every fifteen minutes. That's why the pilot in the airplane has to check his turn by his compass and reset it about every fifteen minutes.

Now it's impossible for us to set up a frictionless bearing so that we will have other forces tc contend with besides the ones I have already mentioned. In calibration we endeavor to cancel out all the forces that it's possible to eliminate. We do this by placing in forces that will react against other forces that are prevailing, thus doing the canceling-out effect and we have an instrument with as near to a zero drift as it's possible to get it.

These are the steps of calibration:

1. Rotor tilt test while instrument is coasting.
2. Rotor tilt test while instrument is running at full speed.
3. Turn table test.
4. Cardinal heading check.
5. Angle tilt test.

In Step One I am getting my instrument as nearly perfectly balanced as possible. If you will run your instrument up on 4 inches of mercury vacuum for 8 or 10 minutes, your instrument will be at full speed. Cage the instrument and shut off your power and uncage your instrument. Let it coast for 5 or 6 minutes and observe the gimbal for rotor tilt. This is done with the 180-degree heading facing you as all tilt is taken from the 180-degree heading no matter which heading you have facing you. If the rotor has a down tilt you will screw the drift nut or horizontal balancing stud in or to the right. If the rotor has an up tilt you will screw the drift nut to the left or out. This procedure has to be repeated until there is positively no tilt in the rotor while the instrument is coasting. This is to insure perfect balance of the gimbal assembly.

In Step Two, you will let the instrument run up to full speed and then cage and uncage the instrument and let it continue to run at full speed. Now observe the rotor for tilt. If any tilt is in the rotor now, it has to be from the nozzle being off centralization. If the rotor has an up tilt, you will screw the nozzle screw to the right or clockwise. If the rotor has a down tilt you will screw the nozzle screw to the left or counter-clockwise. Keep repeating this procedure until there is absoluetly no tilt in the rotor while the instrument is running at full speed.

In these two rotor tilt tests, you are making your instrument as nearly perfect as possible and are calibrating out of it the apparent precession that it will have due to the

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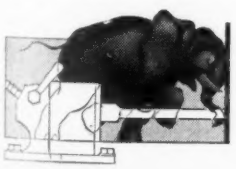

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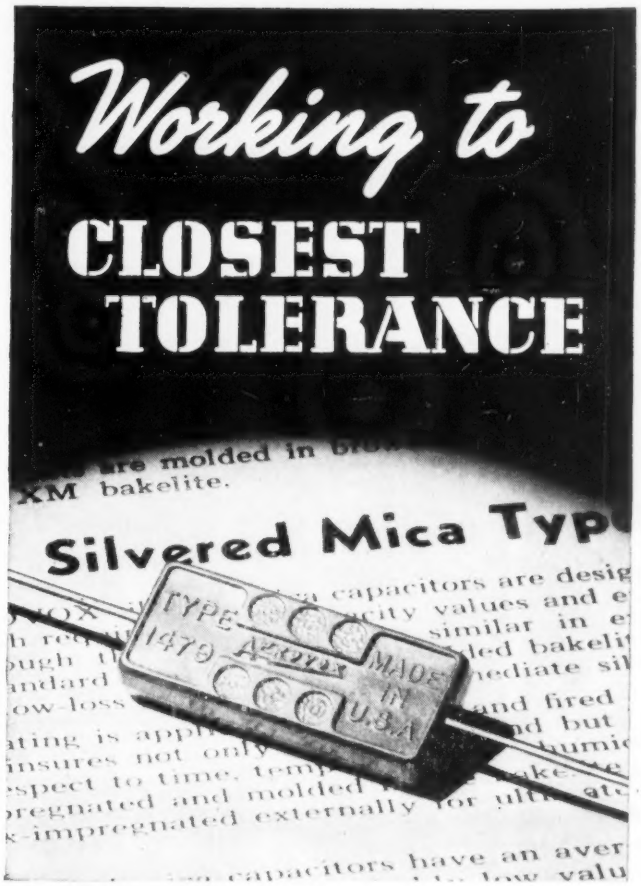

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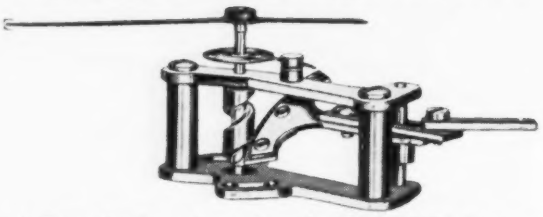

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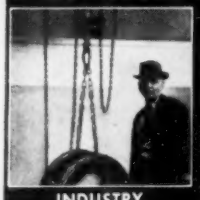
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earth's rotation. Now any precession that you have will be due to other forces such as friction in bearings, etc., that will make it precess off. In assembling your instrument be sure that your bearings are in as good a shape as possible and be sure that you have the instrument assembled correctly, that is, that you have no loose bearings or anything that will produce weight shift.

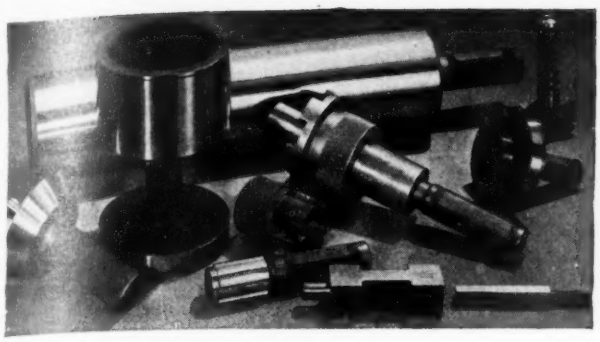
Make tests after each thing you do, to insure that you are assembling the instrument correctly. Your entire instrument has to be as nearly perfectly balanced throughout as possible. If gimbal bearings aren't tight enough in their recesses you are liable to have weight shift from this cause. A test I always use to see if my bearings are tight enough is to place a scribe or jeweler's screwdriver against the snap ring in the bearing assembly and push around in a circular motion. If the snap ring turns and the race remains firm in the recess, it is tight enough. If the race turns when doing this, it is too loose. Test pivots in the vertical ring that fit into your gimbal bearings after you have tightened the lock screws and see if they are tight. If these pivots aren't tight they will loosen up from vibration and allow weight shift of your gimbal assembly in your vertical ring. It is impossible to calibrate an instrument that has any weight shift or isn't assembled properly.

Third Step of calibration (the turn table test) is done for the adjustment of the top pivot and to see if my instrument is absolutely free in the case. It is a test for friction in the top and bottom bearings also. I try to get this top pivot adjusted so that I will have as close to one-degree differential in my readings as it is possible to get it. You are allowed a two-degree differential in this reading but if you stay close to this you are crowding the maximum tolerance and you are liable to have one of your headings show up with too much differential. If your top pivot is too tight or too loose it will give you the same reaction. The only thing if it is too loose you can cage and uncage the instrument and watch the card. If the card moves up or down at all, it is too loose. In assembly I usually tighten the top pivot until the card just starts to move and then I feel the instrument for *end play*. Be sure you do not confuse side play in the lower bearing with end play in the instrument.

By taking the turn table test at this time I save time in my calibration. I could go ahead and do the rest of my calibrating and have everything within tolerance and then take the turn table test last and if I had to do any adjusting then all my time spent in calibration would be for nothing because I would have to do it all over again, so I really save time by doing the turn table test third. If I get the top pivot adjusted to one-degree differential I will find that when I do get my instrument calibrated I will have a half-degree plus with turn table turning to the left and a half-degree minus with turn table turning to the right. Use a turn table with 180 degree per minute turn.

Steps Four and Five can be done on a Scorsby if you have one, otherwise do this calibration in the calibrating fixture. Cardinal heading calibration will vary with various instruments as each turn indicator has its own peculiar characteristics. However, we can set down a few rules that will work on most instruments. If we turn the drift nut to the left it will make the instrument precess plus; if to the right the instrument will precess minus. Turn the nozzle screw to the left and the instrument will precess minus; to the right and the instrument will precess plus. The drift nut will affect the 0 and 180 degree headings most and the nozzle screw will affect the 90 and 270 headings most.

Now if you have an instrument that is giving you a plus reading you will want to make the adjustment that will cause the instrument to precess minus so as to cancel out the drift or plus reading. If the instrument is drifting minus then reverse the adjustment or adjust the instrument to drift plus to cancel out the minus drift. You want to figure each instrument as an individual problem. There are no cut-and-dried laws that will work on absolutely all instruments. However I have a chart I will include in this article that will work on the biggest percent of them and then by the theory of the instrument itself you can figure your instrument out all right. Now if drift nut to the right



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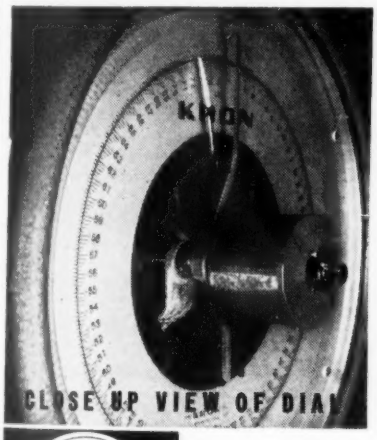
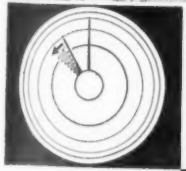
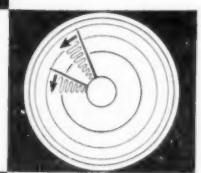
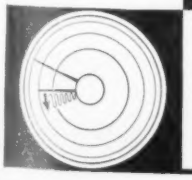




"Magna-Pointer" held at zero before timing interval.



"Magna-Pointer" engages and moves with weigh pointer during interval.



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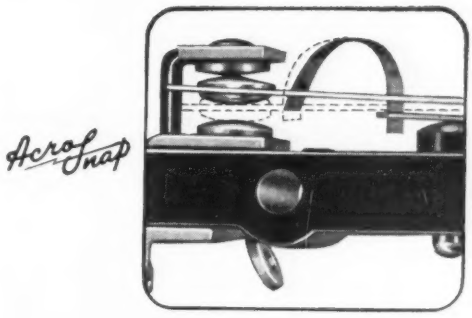

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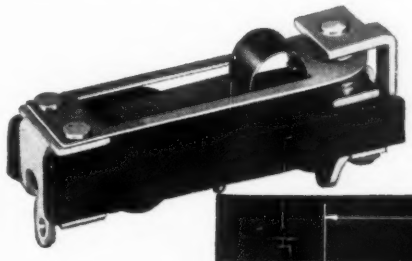
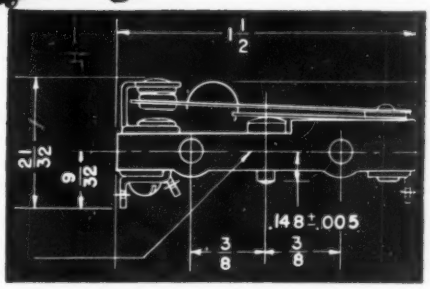


Midget Switch illustrated one-fourth larger than actual size.



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and nozzle screw to the left will make the instrument precess minus, that shows us that we have to adjust the instrument in to an up tilt to make the instrument drift minus. Down tilt to make the instrument drift plus. Now in adjusting or making the adjustments throwing a tilt in your rotor, this tilt will not show up when the forces you are entering in to cancel out the force that originally made the instrument drift off heading, because the forces are equal and opposite and the instrument will not have a tilt and will not drift off when it's adjusted right. What you are really doing is throwing the instrument off balance in the direction that will let you employ the force of gravity to offset the forces of friction (or what have you) that made the instrument precess off. In the case of the nozzle screw adjustment you are employing the force of the air against the buckets of the rotor as the force to cancel out the opposing forces. To save time I generally take all my cardinal headings for a five-minute run each to see which way it is going to drift and then make my adjustments. When I get the instrument so it is holding its headings all right for these five-minute runs, then I will take the regu-

(Continued on page 222)

The Constitution of Matter

(Concluded from page 205)

Fig. 13 shows the arrangement of the atoms of iron in a crystal under different conditions of heat treatment. We still know comparatively little regarding the interatomic forces of iron. We need a force equal to twenty-five tons to tear asunder the particles in a polycrystalline bar of iron an inch thick. This is not nearly so large as what it should be as calculated from our interatomic forces. This discrepancy is due largely to the fact that the bonds be-

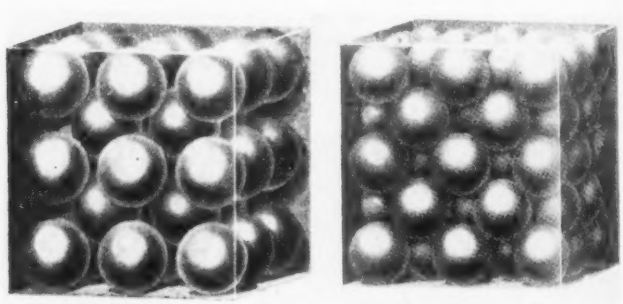

Fig. 13. Iron has a body-centered cubic lattice below 920°C. and is known as alpha-iron (a).
Gamma-iron (b) has a face-centered cubic lattice from 920°C to 1410°C. Iron is most magnetic below 920°C.
(Courtesy Bell Telephone Laboratories.)

tween the atoms do not all give way at once, but go piecemeal, and further, in a polycrystalline piece of iron, we have in many parts of the iron bar only the forces between the crystallites of iron composing the bar and of this we know still less.

When a set of iron atoms like those in *(a)* Fig. 13 is subjected to a magnetic field, the dimensions of such a cube are changed. These are known as magnetostrictive effects. Are the distances between the atoms of iron thereby changed? If so, magnetization should change the hardness of iron. We now know that repeated reversals of a magnetic field applied to an iron rod does soften it.

The word atom comes from a Greek word meaning indivisible. A large part of modern physics is based on the discoveries which have shown that atoms are composed of several parts. The great indoor sport for physicists today is "smashing atoms," for by that process can we learn what the constituent parts to an atom are. Later articles will deal with the methods whereby these constituent parts may be demonstrated. At present there seem to be five different bricks from which atoms may be constructed: protons, positive and negative electrons, neutrons and neutrinos.

Matter, in general, is like a fisherman's net—a lot of holes held together by strings.

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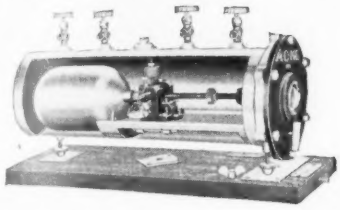

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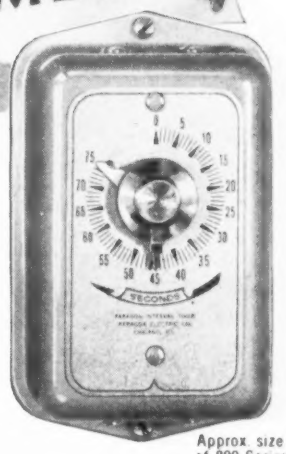

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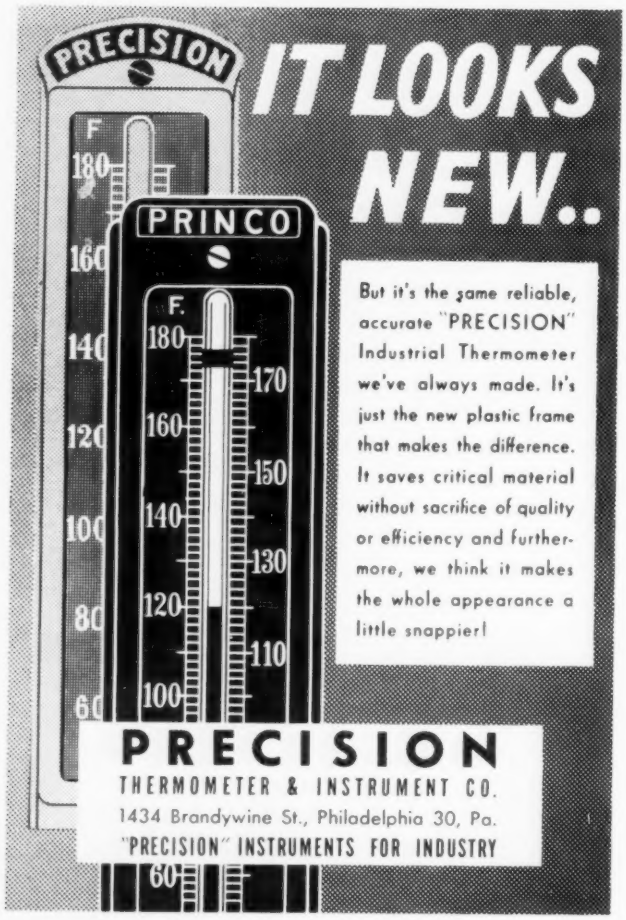
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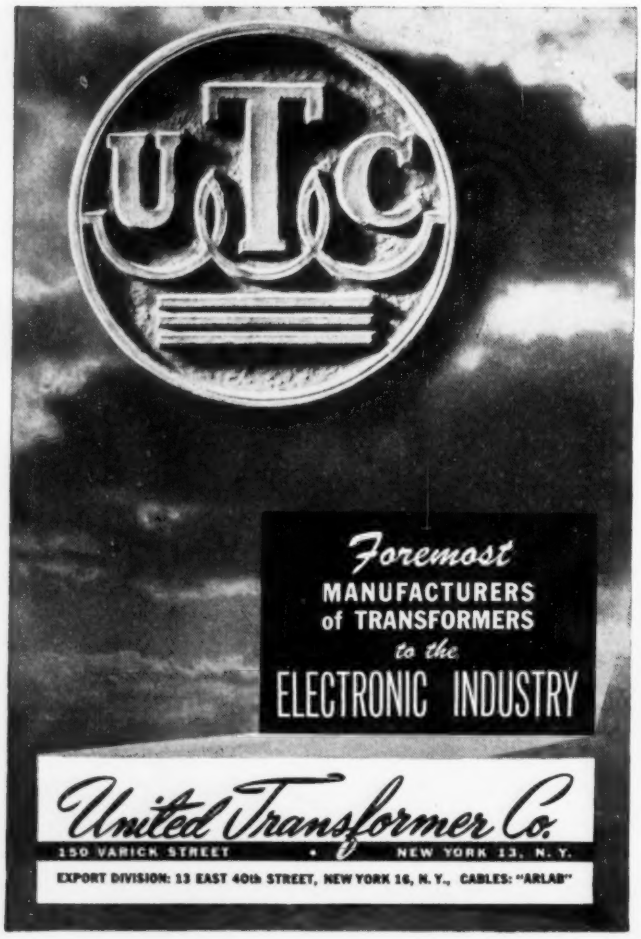

lar twenty-minute run each. We have a tolerance set up of not over a total of twelve degrees on all four headings and not more than five degrees on any one heading.

I think you will all agree with me, though, that an instrument that is just within the tolerance isn't exactly what you would call an excellent instrument; so I always make it a practice to make each instrument a little better than the one before. Yes, I am always striving for perfection. Try to get as near a 0 drift on each heading as it's possible to attain. There will be some instruments that you will have to calibrate absolutely backwards to the accepted rule. If you were to make a graph and list the markings on this graph to arrive to a 0 drift then you will find out that sometimes an instrument will be on the other side of the 0 drift mark and you will have to calibrate backwards to bring the instrument back to the 0 drift. This can be an effect of over-calibration.

You will find also that on some instruments you will have what we commonly call a cross-reading instrument. That is, your corresponding headings such as 0 and 180 instead of being like readings will be opposite, 90 and 270 opposite, for example you could have 2 degrees plus on the 0 heading, 2 degrees plus on the 90 degree heading and 2 degrees minus on the 180-degree heading and 2 degrees minus on the 270-degree heading.

There are three main causes for a condition of this kind. You can have a condition of over-calibration, or an out-of-centralized condition of the rotor in the gimbal ring or an out-of-centralization of the gimbal ring in the vertical ring. If by calibrating the instrument backwards you are getting nowhere, test your instrument for the centralization of the rotor in the gimbal ring or the gimbal in the vertical. Oft times you will have a slight sprung gimbal and you have used a male plug in the 90-degree end of the gimbal in your indicating and you are well within tolerance. If you were to place this plug in the 270-degree end and indicate the plug, you will find that it may be quite a difference in the readings. To really have a centralized rotor in the gimbal ring you would have to divide these two readings so that the rotor would be centralized with the vertical axis of the instrument. For example; we'll say that we have a perfect centralized condition on the 90-degree end of the gimbal. When the instrument wouldn't calibrate out the cross readings we disassembled the Instrument to check our centralization of the rotor in the gimbal ring. We have already checked the centralization of our gimbal ring in the vertical ring and found it to be within tolerance. When we check the centralization of the 270-degree end of the gimbal we find one side 2 thousandths high. Now if we adjust the bearings in the gimbal so that this side is only one thousandths high and we check the 90-degree end and find that it is now one thousandth low, we have divided this error between the two ends of the gimbal and as far as the rotor is concerned it is centralized with the vertical axis of the instrument. Now the instrument can be calibrated. With this out-of-centralized effect in the instrument you have this whirling mass moving about the vertical axis of the instrument and this sets up forces to bring about this cross reading of the instrument. So we have to bring the rotor back within centralization of the vertical axis of the instrument.

In the Fifth Step of calibration (the angle or tilt test) if any out-of-balance of the gimbal assembly or card assembly is present your instrument will drift off. If the gimbal assembly is top-heavy or bottom-heavy you can take out most of this drift by adjustment of the vertical balancing stud. If the drift is caused by out-of-balance card, then the only way to calibrate the instrument is to check the card for balance and balance it perfectly. By adjustment of the vertical balancing stud on the gimbal you are only correcting the top or bottom heaviness of the gimbal assembly by balancing it perfectly. This test is done on a 15-degree right and left angle on the 45- and 90-degree headings on each angle. Run instrument for 10 minutes on each of these headings and the maximum tolerance allowed is 4 degrees plus or minus on each heading.

If you have been using a Scorsby in your calibration,

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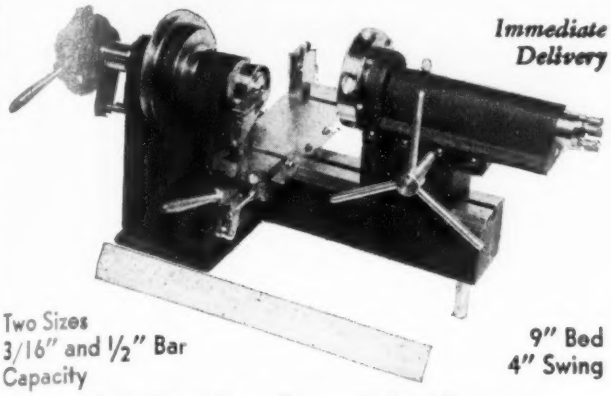

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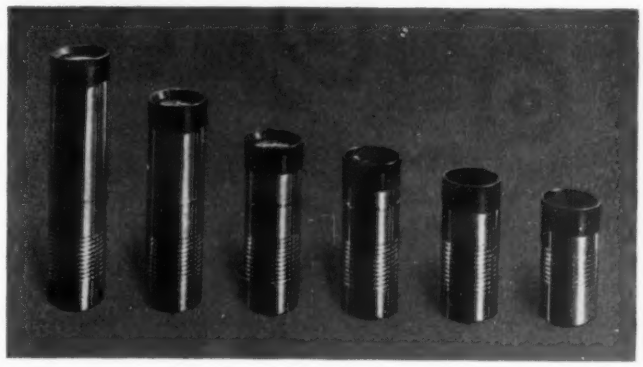

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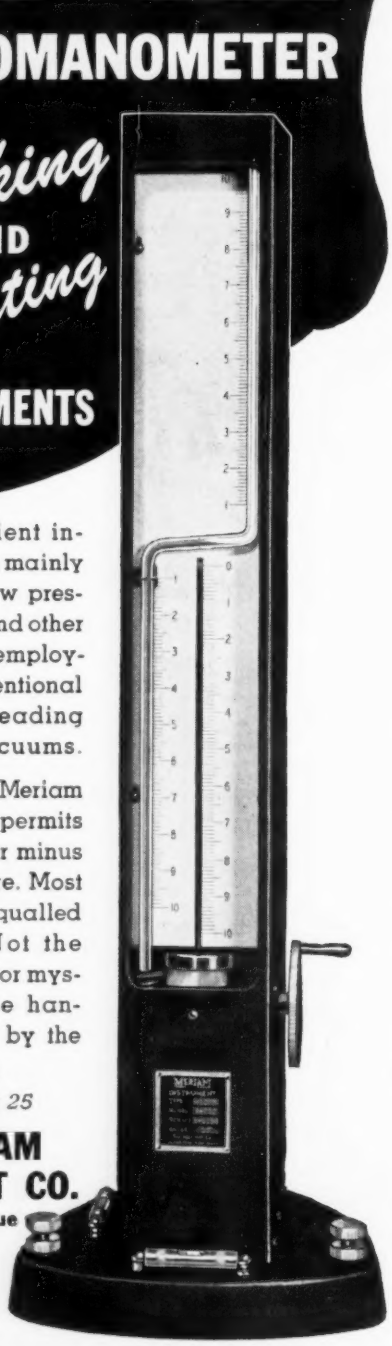

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The following table might help some of you in your calibration problems:

ANGLE TEST OR TILT IN FIXTURE

ANGLE	DRIFT	CORRECTION
LEFT	PLUS	VERTICAL NUT UP
LEFT	MINUS	VERTICAL NUT DOWN
RIGHT	PLUS	VERTICAL NUT DOWN
RIGHT	MINUS	VERTICAL NUT UP

CARDINAL HEADING TEST

DRIFT	TILT OF ROTOR	COMPENSATE
MINUS	UP	DRIFT NUT OUT OR TO THE LEFT
MINUS	UP	NOZLE SCREW TO THE RIGHT
PLUS	DOWN	NOZZLE SCREW TO THE LEFT
PLUS	DOWN	DRIFT NUT IN OR TO THE RIGHT
ZERO	UP	NOZZLE SCREW TO THE RIGHT
ZERO	DOWN	NOZZLE SCREW TO THE LEFT
PLUS	ZERO	DRIFT NUT TO THE RIGHT
MINUS	ZERO	DRIFT NUT TO THE LEFT
	ROTOR	

SHORT COAST WITH MINUS DRIFT, OPEN 180-DEGREE SIDE
SHORT COAST PLUS DRIFT, OPEN THE 0-DEGREE SIDE
LONG COAST PLUS DRIFT, CLOSE THE 180-DEGREE SIDE
LONG COAST MINUS DRIFT, CLOSE THE 0-DEGREE SIDE.

Rotor tilt, 1/32" maximum.

As a rule, 15 degrees is equal to one turn of the nozzle screw; one degree is equal to one face of the drift nut.

On the majority of instruments that you will work on, you will find that after you perform the first three steps of calibration I have set down here you won't have any trouble when you take your cardinal heading check. (That is, if your instrument has been assembled correctly). The cardinal heading and angle tests will be mostly checks you'll have to do but the instrument will be well within tolerance. However, I have tried to give you a few things to check if you run into trouble. I sincerely hope that I have cleared up a few of the things that have been bothering you in your calibrating problems.

Electron Tube Applications

Continued from page 209

It is for the purpose of preventing this reverse current that the suppressor grid is introduced. This is illustrated in Fig. 97. The suppressor grid, as has been explained, is usually connected directly to the cathode so it is at zero potential with respect to the cathode; it is, however, at negative potential with respect to the plate, hence a field is set up between the suppressor grid and the plate as shown in Fig. 97. This, in effect, restores the condition present in Fig. 95. It will be seen that the same number of lines of force terminates on the plate as in Fig. 95. It is evident, therefore, that in this instance the secondary electrons will also be driven back to the plate. The suppressor grid, however, has little effect upon the high-speed electrons traveling from the cathode and accelerated by the control grid and the plate potentials.

In operation and in the method of its use in circuits, therefore, the pentode does not differ materially from the screen-grid tetrode. It is applicable as a radio-frequency voltage amplifier and can also be used as an audio-frequency voltage amplifier to give high voltage gain per stage. ("Audio" means the audible frequencies 0 - 10,000 or 15,000 cycles per second.) Like the tetrode it has a high amplification factor. It is furthermore suitable as an audio-frequency power amplifier. When the tube is used as an audio-frequency amplifier, the function of the screen grid is chiefly

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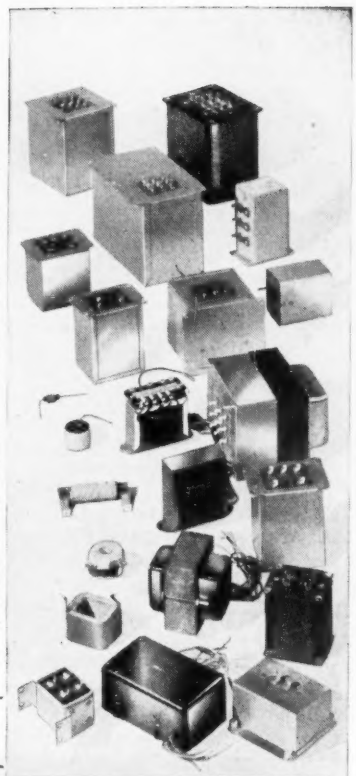

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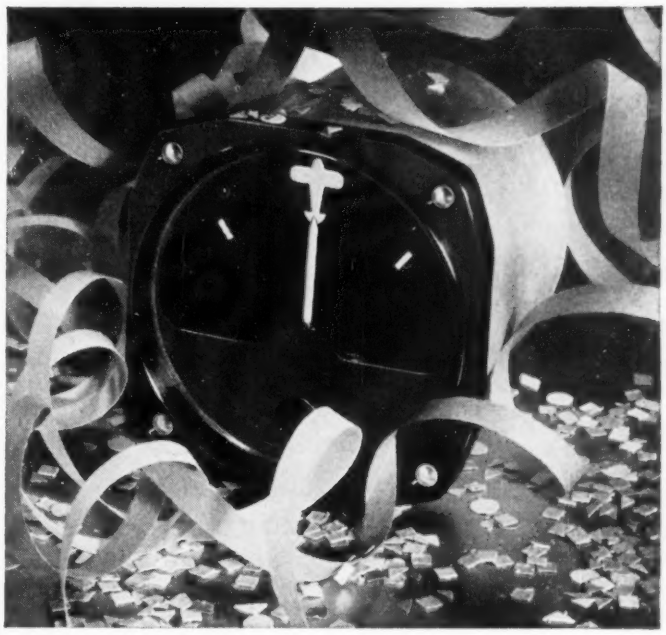

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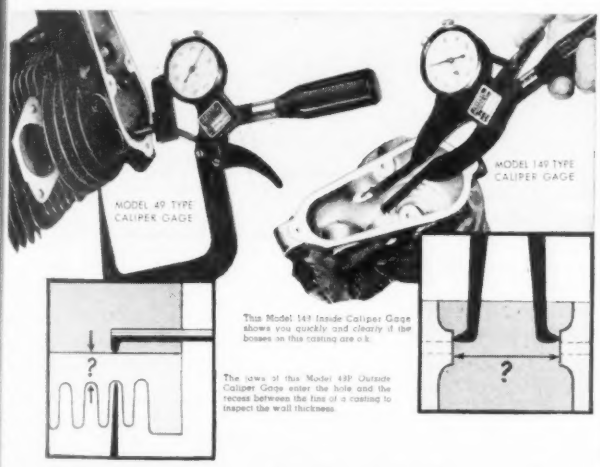
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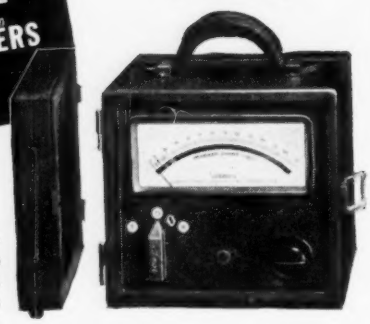

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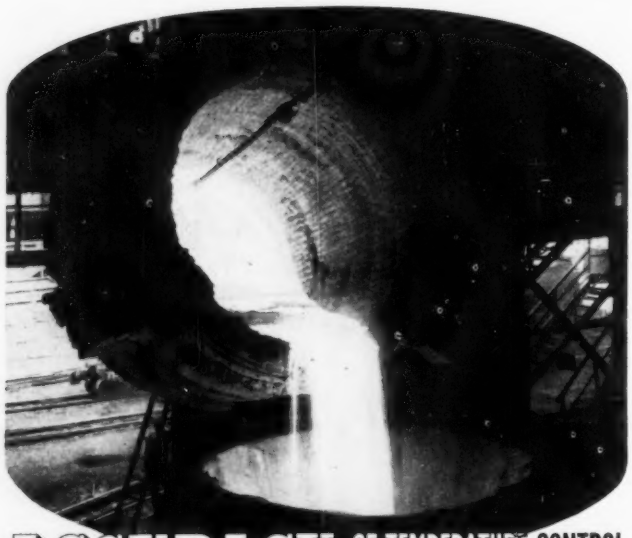

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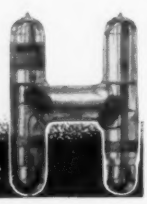

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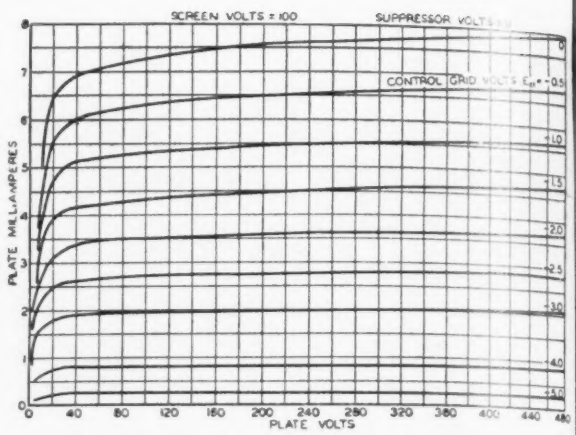

Fig. 98. Suppressor grid characteristics. The initial downward slope of the screen grid characteristic, it will be noticed, has been eliminated and the curves rise smoothly and gradually become flat.

that of accelerating the electron flow rather than shieldin so that when used for this purpose the "screen" grid often called the accelerator grid.

Typical plate current characteristics for a suppresso grid pentode are shown in Fig. 98. The initial downwar slope of the screen-grid tube, it will be seen, has bee eliminated and the curves rise smoothly and gradually b come flat as the saturation point is reached.

So much for the pentode, at this point at least. It is n the purpose here to enter in too detailed a discussion these various tubes or to become too deeply involved in study of their characteristics. It is of interest, however, know that merely by the addition of various elements, tub can be designed to have certain characteristics. The add tion of the "screen" eliminated the undesirable capaci effect of the triode but at the same time introduced a ne undesirable effect. The addition of still another elemen the suppressor grid, eliminated this new undesirable effe and provided a tube with no capacity effect and with hig power-amplifying properties.

Insofar as industrial instrument applications are co cerned, this is about as far as we need go in tube desig Tubes with larger numbers of elements are made chief for radio and laboratory purposes. Many of these tub combine several distinct functions.

Fundamentally, all these tubes are rectifiers and ampli fiers, and therefore can also serve as oscillators. This b ing so, the question arises why a four- or five-electrode tub would be used as an oscillator when the screen was intro duced specifically to prevent oscillation. The only situa tion where oscillators with four- and five-electrode tube are preferred to oscillators employing the simpler and les expensive triode is where it is desirable to avoid energ transfer between the input and output circuits of the tub through the grid plate tube capacitance. Such oscillator can be made more stable and also the highest frequency that can be obtained is higher than in tubes where th capacity effect is present.

Those primarily interested in industrial instrument ap plication need have little concern with all these variou developments in tube design.

If, however, it be kept in mind that the multi-elemen tubes, the tetrodes, the pentodes, hexodes, penta-grid con verters, etc., are merely extensions of the triode, the ap parent complexity of the subject will largely vanish.

There are other electron tubes (one in particular, th photoelectric tube) which are used in industrial instru mentation and which will be considered later, but these are tubes of a special nature and not part of the thermioni tube family. Likewise of a special nature are the cathode ray tube and the modern X-ray tube though in their present day forms they are mostly thermionic tubes.

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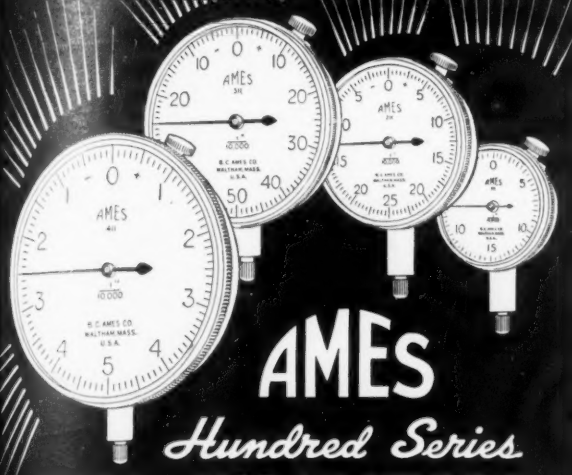

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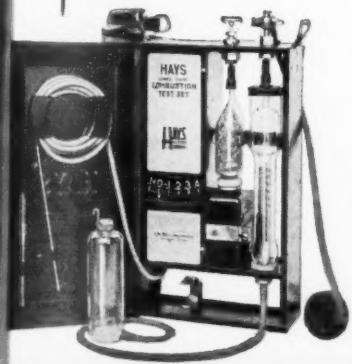

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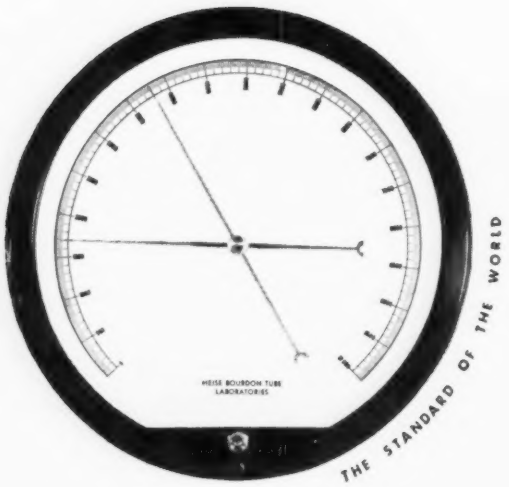

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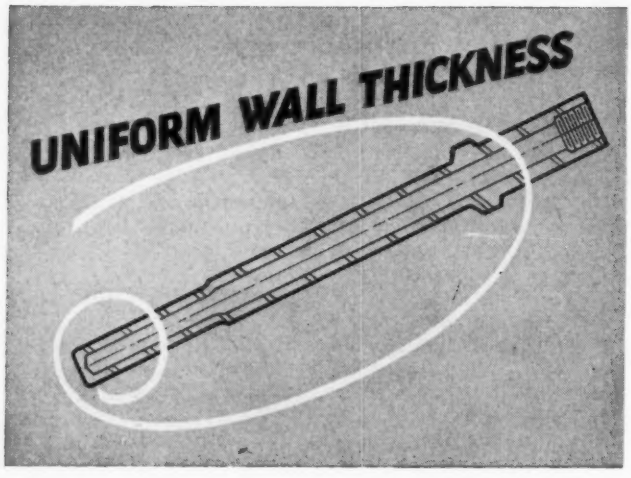

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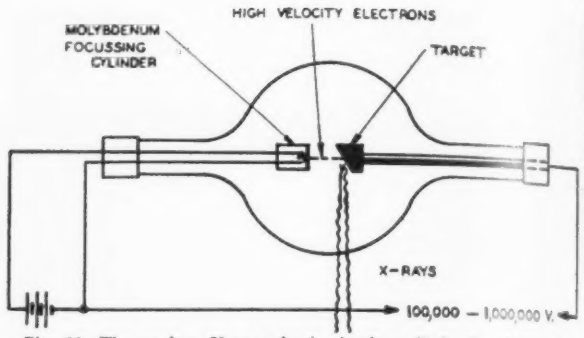

Fig. 99. The modern X-ray tube is simply a diode. Its electrodes are of special design and material and the plate potential is in the order of hundreds of thousands of volts.

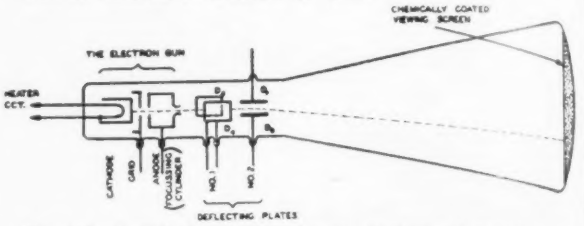

Fig. 100. A typical cathode-ray tube, showing the arrangement of the electrodes.

is made in the form of a target as shown in Fig. 99. This impact so disturbs the atomic arrangement of the material (usually tungsten) of which the anode is made as to cause it to emit energy in the form of short-wave radiation, known as the X-ray, the wavelengths of which range from one-fiftieth to one-thousandth of the visible wavelengths.

The modern X-ray tube is similar to the ordinary diode insofar as its electrodes are concerned. The electrodes, however, are much farther apart and the potentials applied to the anode are very much higher, usually of the order of hundreds of thousands or even millions of volts.

The cathode-ray tube used in the cathode-ray oscilloscope is in some ways similar to the X-ray tube but the stream of electrons, instead of striking a small anode, impinges upon a chemical coating or deposit on the inside of the end of the tube. The impact of this electron stream causes fluorescence in the chemical screen. By means of suitable focusing methods the electrons emitted by the cathode are concentrated in a very thin stream so that only a small spot of light is formed. These electrons, since they carry electric charges, can be attracted or repelled by electric and magnetic fields, hence by arranging electrodes or magnets on either side of the electron stream as shown in Fig. 100, and by applying voltages, or magnetic fields, the electron stream will be deflected, depending upon the voltage applied to the plates or coils.

The typical cathode-ray tube shown in Fig. 100 has seven useful electrodes: heater-cathode, control grid, anode assembly and two pairs of deflection plates, Nos. 1 and 2. The assembly of the cathode, grid, and the focusing anode is known as the electron gun. The electrons furnished by the cathode are controlled, accelerated, and focused by the other gun electrodes into a tiny beam, the cathode ray.

To obtain a useful pattern or wave form, it is necessary to move the spot horizontally, back and forth across the screen at some convenient frequency and with some suitable motion with respect to time. This produces a horizontal line of narrow width (equal to the diameter of the spot) in the middle of the screen. The horizontal motion or "sweep" is obtained by applying a suitable alternating potential across the deflection plates D_1 and D_2.

The voltage to be studied is applied across the deflection plates D_3 and D_4 which are placed at right angles to the deflection plates D_1 and D_4. Thus, under the action of the two voltages, the luminous spot is moved not only back and forth but also up and down. This movement produces a tracing of the desired voltage wave under inspection.

This briefly outlines the principle of the cathode-ray tube. Its application as an oscillograph or an oscilloscope entails complications that need not be considered here and they in no way affect the operation of the tube.

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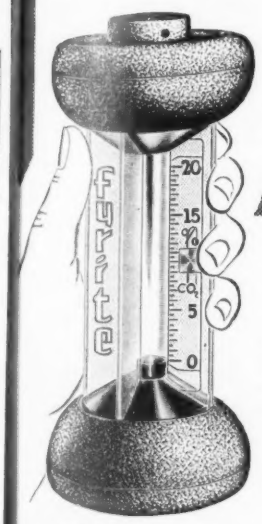

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FYRITE CO_2 readings instantly expose fuel wasted up the stack, indicating necessity of making adjustments that will secure the most efficient combustion. The FYRITE also helps detect heat losses due to air leaks in boiler settings, etc. It is indispensable to "cross-check" automatic combustion controls, and to assure proper compensating adjustments in the fuel-air ratio. The FYRITE is simple, rugged; has no valves, clamps, or leveling bottle; no glass parts or batteries. 10,000 FYRITES are in use.

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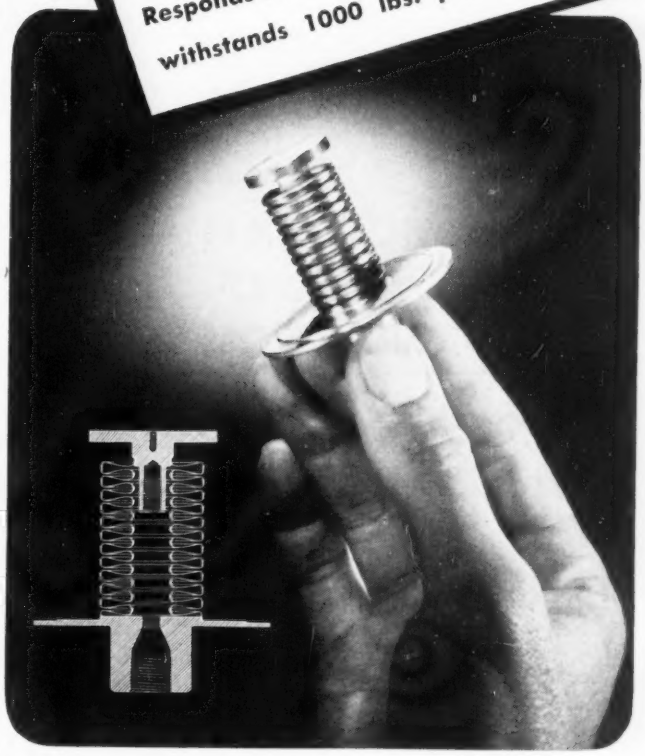

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. . . this small bellows measures only ¾" in diameter and has the ability to accurately register oil pressure from 0 to 400 lbs. p.s.i., and to return to within .0001 inch at any given pressure after the maximum pressure has been applied. This is accomplished without a spring return since the bellows is inherently a true spring. This small bellows is particularly adaptable for instruments and other uses where calibration must be held to extremely close tolerances.

Cook "Spring-life" Bellows' sensitive dimensional response to small increments of pressure is a matter of the degree of flexibility within the bellows units. Flexibility varies directly with the number of flanges, width of the flanges and type and thickness of metals used.

Cook "Spring-life" Bellows may be constructed of tinned phosphor bronze, high carbon steel, Monel, Inconel, copper, stainless steel or beryllium copper, brass and any other metal to suit your requirements. Cook construction places no limit on the number of diaphragms or free length of a single unit.

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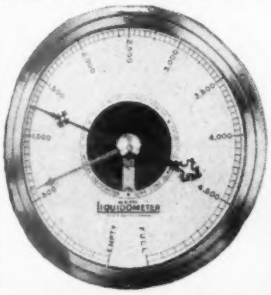

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Oil Refinery Instrumentation

Continued from page 201

line, the pressure tap on the downstream side of that valve will change its pressure, thereby repositioning the diaphragm valve, allowing approximately the same amount of gas to pass through to the heater of this unit. Now if the outlet temperature changes, we get a new loading pressure on the top of the diaphragm, and this will give us a change in gas pressure and volume to the still.

This type of installation has proved satisfactory in most cases, but it does not take into account the change in Btu. content of the gas. It is true that when the Btu. content changes, the temperature of the oil outlet will change and that the temperature instrument will reset the balanced pressure valve. However, there usually is quite a long process lag and if the Btu. content of the gas is changing considerably (this is not uncommon) then we find the instrument must be continually changing to compensate or to hold the outlet temperature at a desired point. In most cases, the controlled outlet temperature will do considerable weaving, which in turn, if we follow the process through, will tend to upset the entire unit and place the rest of the controls on an oscillating cycle. Owing to the conditions of the types of gases used, through this balanced pressure valve, we find that a slight sticking action of this valve will cause considerable trouble which is difficult to determine and eliminate.

Now, with the proper knowledge of the measurement of flow and flow theory, we find that by installing a flow controller in this gas line and having it control a balanced V-port valve with a valve positioner mounted on top to assure definite positions for each change in loading pressure, we have a rate-of-flow controller that will hold any predetermined rate we establish. Since this gas has a nearly direct relationship between gravity and Btu. content, as the Btu. content changes the gravity changes also and the principle of flow measurement is based on the weight of falling bodies. We then have a change of flow through the orifice plate for any slight change in gravity or pressure. Since this is a flow control, and the rate changes in either direction, the controller will adjust the valve to compensate for these changes. We should remember at all times that such a flow controller is merely a differential pressure controller maintaining a constant predetermined difference in pressure across a fixed restriction in the flow line. The average instrument man, with insufficient knowledge of flowmetering theory, would not be able to understand this application. It is only necessary now to take the heater outlet temperature, attach a temperature controller of a suitable type to that temperature, and instead of controlling the pressure valve as was the case in the first set-up, merely reset the control index on the flow controller. And now, any change in temperature will call for—and get—a different rate of flow of fuels to the heater.

This is only one case where the importance of theory is brought out. Time will not permit us to go through dozens of other cases that could be readily cited.

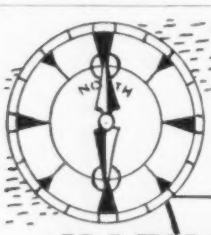
INSTRUMENT SHOP LAYOUT AND ROUTINES

Let us take a few minutes to outline some of the requirements of an average well-equipped instrument shop and to discuss some of the checking and testing procedures.

First, the shop or laboratory should be centrally located in respect to the operating equipment.

It should be of sufficient size to accommodate at least two large workbenches with two or more vises for heavy work such as flowmeter repairs. Tool drawers should be included. Light benches or tables for pyrometers and other electrical work are necessary. In the larger plants a clock repair section is included, with a watchmaker's bench, lathe and other small tools. A large part of a wall can be used for parts, lockers and drawers, with each section marked as to manufacturer and, on each drawer, the actual part listed as to part number, etc.

Another section of the room should contain a pressure gage tester with sufficient room to handle these parts



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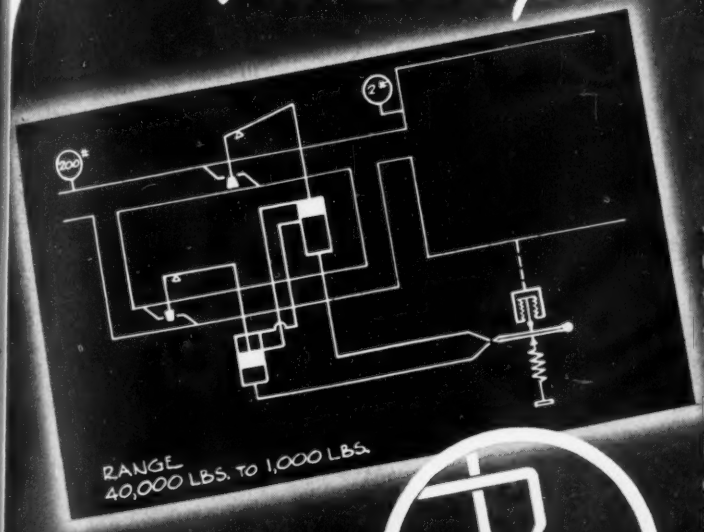

EXTREME PRESSURE REDUCTION AND WIDE FLOW RANGES

...and here's how it's done...the Askania Regulator operates two control valves through two series-connected cylinders, as shown in the accompanying diagram.

By this means, steam pressure reduction from 200 lbs. to a controlled pressure of 2 lbs. is maintained accurately over a range of 40,000 lbs. of steam per hour to 1000 lbs. of steam per hour. The installation described has been in continuous operation for the past eight years.

For full details on this, or any other pressure reduction problem write...

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and gages to be repaired. A deadweight tester is required for higher pressures and a water column glass for the lower pressures. A vacuum pump is often required for pressures below atmospheric.

A section is required in almost every shop for making and testing thermocouples. Either an acetylene welding outfit or an electric welding outfit is necessary to weld the couples. Large shops will have both. Much care must be given to the forming and welding of couples since it is too easy to destroy the homogeneity of the wire during straightening, forming and welding. Couples should then be checked against a calibrated standard thermocouple. This standard should be returned to the original factory at regular intervals for rechecking since it also may change after heating and cooling several times.

As mentioned previously, a complete library consisting of instruction books and other data should be maintained as ready reference on at least the equipment in the plant.

In the shops of the larger plants a full-time lathe operator is employed to make small parts needed for quick repairs on instruments and control valves. Some of the plants allow the machine shop to make these repairs. In my estimation this is strictly an instrument man's job. Since he is responsible for the proper operation of the control instruments he must also know the condition of the valve, as many times a sticking valve is the real cause of improper control. Where valve positioners are used the machinist seldom knows how to properly adjust this mechanism, which is as important as any other part of the whole control system.

The normal utilities are required in the shop: gas, air, water and electricity. Suitable pressure-reducing valves and transformers are needed to provide pressures and voltages as required for various forms of testing.

Each man should be provided with a separate tool box or drawer since no mechanic enjoys sharing personal tools with another. They will keep their tools locked up to prevent loss or mistreatment.

Some of the common questions asked regarding maintenance routine are: How often should I check a—

Thermometer?	Thermocouple?
Millivoltmeter?	Flowmeter?
Potentiometer?	Pressure Gage?

Neither I nor anyone else can answer these questions without first asking you a few, such as—

1. What is the application?
2. How important is it?
3. What kind is it?

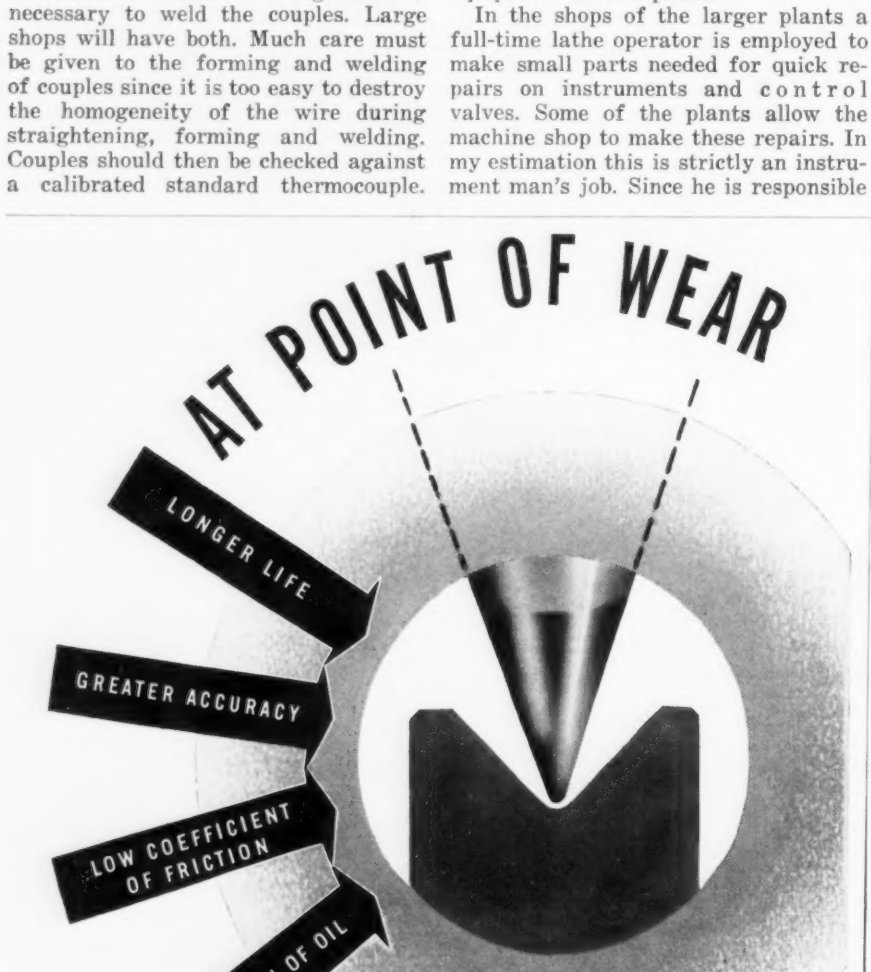
The answers to these three questions will determine the proper answer to be given to your question.

Let us for example take a flowmeter. If it is properly installed on a water line of secondary importance and if it is a mechanical mercury float type with greased pressure-tight bearings, it can be considered to be as correct after three to six months' service as it was the day it was installed. However, if this same meter was installed on an oil line feed to a still and perhaps controlling that feed, its "correctness" would be extremely important. Furthermore, there are cumulative troubles on oil pressure that we do not find on water lines; for example, condensate may collect in one side or the other of the meter, causing it to read incorrectly and causing the operator to feed too much or too little through the unit. Therefore, it may be advisable to check such a meter for zero as often as *once each day*. This is especially true in these times when all units are working at fifty to seventy-five percent over their rated capacity.

Next, let us take a potentiometer. Since this is the most accurate means of measuring temperature with a thermocouple, instrument men who take its accuracy for granted are inclined to neglect it. Although some potentiometers have automatic standardization, the batteries must still be changed, slidewires cleaned, and so forth. Now, add two more questions to the three stock questions that we listed for flowmeters:

4. How much vibration is apparent?
5. How dirty is the location?

All potentiometers have galvanometers with the exception of a recently developed type based on electronic



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rinciples. Those with galvanometers re affected by dirt and vibration. Where this is apparent, it may be ecessary to check the instrument for echanical and electrical balance *each* ay. Where the instrument is in a comaratively clean atmosphere with norial ambient temperatures, and no ibration, it may run for weeks without ny attention.

How long will a thermocouple last nd hold its original temperature-e.m.f. haracteristics? If someone could give definite answer to this question, or a ixed rule, I can assure you that he ould be quite popular.

Thermocouples are affected chiefly atmospheric conditions, changing mperatures and vibration. If the atosphere remains exactly the same, if e temperatures remain the same, if here is no vibration, and if the homoeneity of the wire is the same from ne couple to the next (and all of these s are practically impossibilities indusially) then we could only tell you bout how long the thermocouple will st and be accurate.

The approximate life of a couple can e estimated when all the facts are nown and then only by past experience n each individual application. Try to ick a safe limit of time dependent on he importance of the application, and hen periodically renew the thermoouples. It is not advisable to move a ouple from one location to another, r to change its immersion depth, nce the temperature gradient along ny couple will change its homogeneity hich, in turn, changes its e.m.f. charteristic.

I believe that all of you will agree hat the plant instrument man's job is tough one. Many of us can do a lot o make his job pleasanter and easier f we at all times remember the probms that he is faced with. The instruent companies can prepare and furish literature. They can supervise and onduct short talks on certain applicaions and equipment and, in general, e very helpful to the education of the lant instrument man. I trust that this hort talk this evening has given you better understanding of the problems o be faced by the industrial instruent engineer and the industrial manement he works with in these various ompanies.

Although the heading of this talk entioned oil refineries, it can be seen hat, with a few changes, it can be ade to include almost any industrial lant using instrument equipment. The umber of men required in each plant ill alter the procedure somewhat, but ll in all they have the problem of conmually educating instrument maintenance men on the present equipment nd keeping them up-to-date with the dvances in this field.

It is certain that the post-war period ill bring many advances to the industrial instrument field, so that suitable raining programs will have to be tarted to allow the instrument man he "breaks" to which he is entitled.

on

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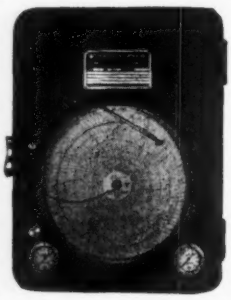

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Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

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The Month's NEW INSTRUMENTS

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New insertion type or "embedded" type unit, when inserted into a strategically located well, is said to eliminate or supersede spark plug gasket thermocouple. Thereby, it is said, new couple fulfills primary purpose of cylinder head temperature determination, i. e., to ascertain any local condition of overheating from poor airflow or other causes. Originally designed and engineered by undersigned company, quick-disconnect bayonet unit has been released royalty free to the aviation industry. Thermocouples are available as individual units or any number woven as an integral part of a harness for compact and simplified multi-cylinder installation. — *The Revere Co., Dept. I, P.O. Box 304, Wallingford, Conn.*

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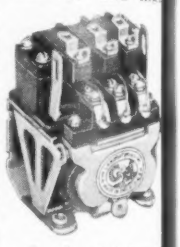
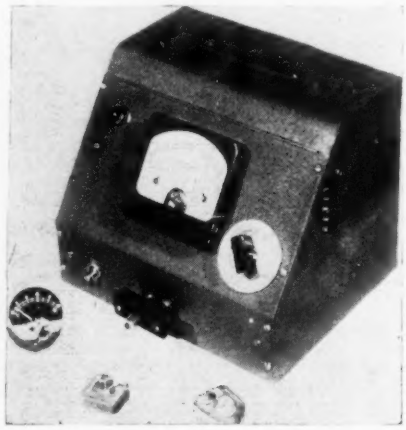


Fluxmeter

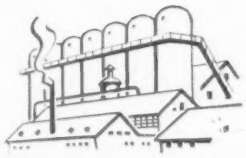
New "Electronic Permeability Comparator" for convenient testing of permanent magnets is said to be a new electronic type of fluxmeter originally developed for maker's own purpose as an aid in production of radio and radar instruments: it served this purpose better than "any other device" maker used, is therefore made available to manufacturers, research laboratories, etc. It may be used for checking and comparing the magnetic flux of permanent magnets of any shape or type. Designed primarily for checking the saturation of special Alnico instrument magnets, new fluxmeter can be used for comparing various types of magnet steels and magnet alloys. Different sizes and shapes of search coils may be used, some of these search coils being small enough to insert in the air gaps of assembled instruments. This new permeability comparator has no moving parts (except the indicating instrument). Ie employs a special vacuum-tube circuit operating from commercial a-c supply.— *J. Thos. Rhamstine, 302 Beaubien St., Detroit 26, Mich.*



Fluxmeter

New fluxmeter, for measuring either flux density or the total magnetic flux in magnetic circuits in research, testing and production work is said to be applicable wherever permanent magnets or d-c. electromagnets are used. It is similar to a light-beam galvanometer and has a suspension-type element. With search coils (easily constructed by user) it permits making a wide variety of magnetic measurements. Seven interchangeable galvanometers are available, with various characteristics whereby flux sensitivities from 101 to 3275 lines/mm. are obtainable on the 300-mm. scale which is marked 50-0-250. Galvanometers are of the "compensated" type whereby restoring torque of the suspension is, for all practical purposes, eliminated, resulting in a fluxmeter construction said to be "excellent for work with electric measuring instruments, communication apparatus, motors and generators and contactors and relays. After a flux change has been indicated, the light beam index remains at the point, giving ample time for accurate readings." Control box contains

MECHANICAL GUARDIANS FOR CHEMICAL PIPE-LINES



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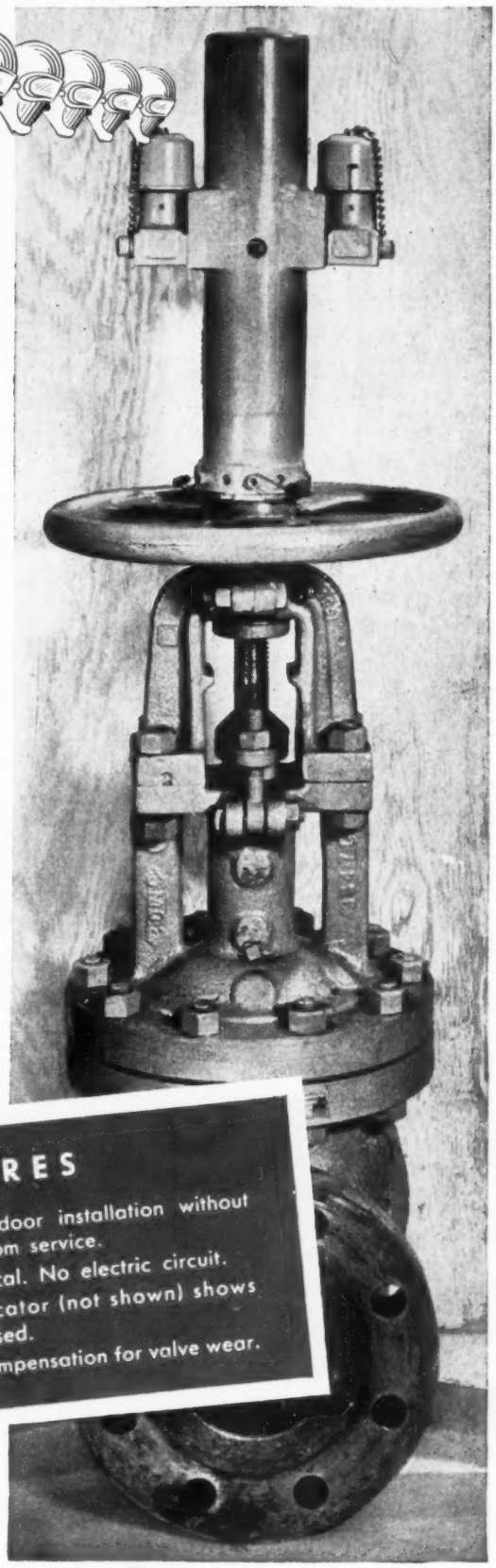
As safety men of the Bendix "Invisible Crew," BENDIX-CORY SAFETY INTERLOCKS are dependable guardians for your pipe-lines. Write for full information.



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- Fully mechanical. No electric circuit.
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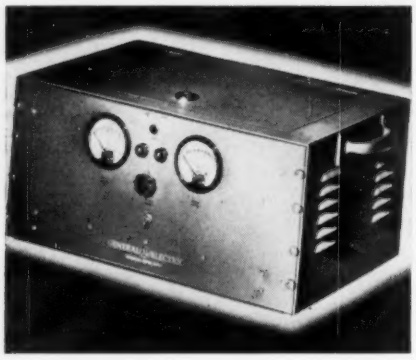
REGULATED POWER SUPPLY



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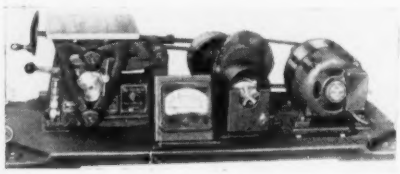
dry cell, resistors, rheostat, push button and switch, provides a means of returning spotlight index to zero after a measurement has been made. It also provides a means of introducing a voltage into the electric circuit to compensate for small but undesirable spurious voltages that may otherwise cause errors in high-sensitivity instruments of this type.—*General Electric Co., Schenectady, N. Y.*

Vibration Fatigue Tester with Automatic Cycling

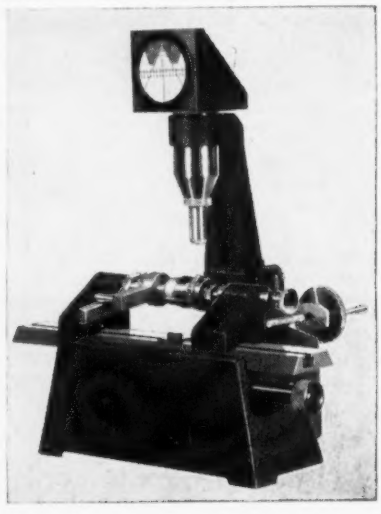
New "Model 10V" vibration fatigue testing machine features automatic cycling, handles parts or assemblies up to 10 lbs. in weight, is said to be ideal for plants



making small electronic, electrical and mechanical parts. Table (8″ × 8″) has drilled and tapped holes for attaching work to undergo test, is mounted on V-frame to minimize stresses on eccentric and connecting rod. Vibration mechanism runs in an oil bath. Vibration, in simple harmonic motion, is produced vertically. Acceleration, or rate of change of velocity, is controlled automatically by a device which changes frequency from 10 to 55 c.p.s. (600 to 3,300 vibrations per minute) and back to 10 c.p.s. continuously and uniformly, complete cycle requiring one minute. Acceleration can also be adjusted manually from 10 c.p.s. to 60 c.p.s. Frequencies are indicated on a sensitive electric tachometer. Maximum capacity is 37*g* (approx.). Base is drilled at corners for bolting to a bench or studs set in concrete. Unit is powered by ½ h.p. 110-v. 60-cy. a.c. split-phase motor.—*All American Tool & Mfg. Co., 1014 Fullerton Avenue, Chicago 14, Illinois.*

Thread Pick-up Projector

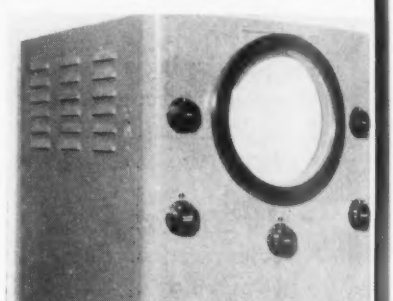
New thread pick-up projector is an optical device for pre-setting driving dog on pre-threaded work, so that when such work is placed in grinder, grinding wheel enters trough of oversize thread to remove finishing stock from both flanks without further adjustment. No time is lost in operation since it is performed on each piece while preceding piece is being ground. Device is said to greatly increase productivity of thread grinders, effect important economies and improve quality of ground threaded parts. It is a rugged special-purpose projector designed particularly for shop use, and permit beginners to pick up the thread after a few minutes' demonstration. Unit simplifies this operation,



making it practical to follow the sched "precut—harden—finish grind." This duces grinding time because only one p of grinder will meet most production quirements. Wheel and diamond life prolonged. Case-hardening stock can used instead of tool steel. Inspection thread angle and root depth is made same setting by means of graduations viewing screen at top. Projector acco modates work up to 4½″ diam. and 1 long, will work in conjunction with a thread grinder. Image is clearly visib even in rooms brightly illuminated by su light. No hood is required. Screen is rul with a 60° V plus other graduations indicate depth of root on American N tional Threads. Supplemental graduatio on same screen permit Acme and Whi worth Threads to be picked up. Speci screens are also available.—*Acme Industri Co., 200 N. Laflin St., Chicago 7, Illino*

Winding-insulation Tester

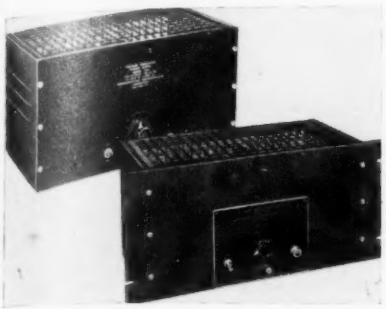
New winding-insulation tester, for pr duction-line testing of faulty insulation an winding dissymmetries in motors, gener tors, coils and transformers, employs prin



ciple of balance and comparison, simultaneously tests turn-to-turn, coil-to-coil, and coil-to-ground insulation. It simulates qualitatively such procedures as resistance, impedance-balance, turn-balance, and complete high-potential tests with one voltage application. It is said to be particularly desirable for testing completed windings of three-phase low-voltage rotating machines, although it is capable also of testing windings of single-phase, two-phase, and d-c. motors and transformers whose insulation is not designed to withstand more than 10 kv. when used to test a three-phase motor, its three leads are connected directly to the three motor leads. After the circuit in tester is energized, any two phases of the motor (1-3, 2-3, 1-2) can be tested quickly by means of a four-position, hand-operated selector switch on front of instrument. Short circuits or grounds in any part of winding are indicated on the oscilloscope by two waves dissimilar in shape and amplitude. Single-phase motors are tested similarly, and d-c. motors by bar-to-bar comparison methods. In both cases, divergence between the two waves on oscilloscope indicate presence of faults. New tester consists of a repeating-type surge-voltage generator, a cathode-ray oscilloscope and synchronously-driven switching equipment, all enclosed in a steel cabinet designed for bench mounting. Oscilloscope is mounted at eye-level and all controls are conveniently arranged. Adequate safety protection has been built into equipment.—*Special Products Division, General Electric Co., Schenectady, N. Y.*

Voltage-regulated Power Supplies

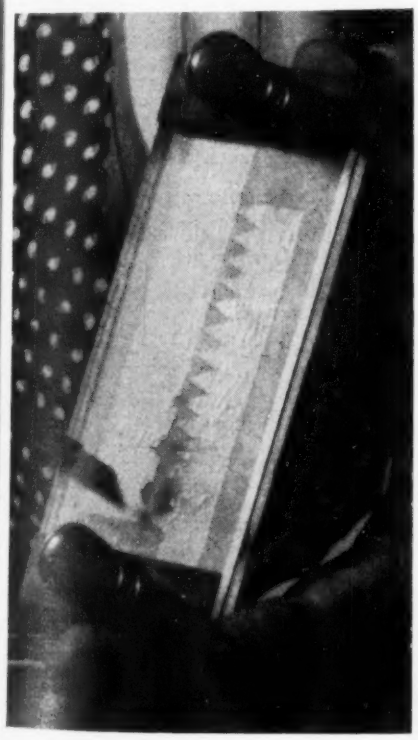
Two new "1100 Series" power supplies differ only in construction: "Model 1100" is a table model for use in laboratory; "Model 1110" is designed for rack mount-



ing. Both use series regulator circuit. To insure low noise level and better regulation, a high-gain two-stage control circuit is used instead of conventional single-stage circuit. High-voltage output can be shifted through a range of 225 to 325 v. by control on front panel. Maximum current drain is 200 ma. from 225 to 300 v. and 180 ma. from 300 to 325 v.; sum of all a-c. components present in output is < 5 mv.; change in voltage output from no load to full load is < 1 v. Primary of poyer transformer is tapped for use at 105, 115 and 125 v. on a 50-60 cycle source. An unregulated heater supply winding of 6.3 v. at 5 amps is furnished.—*Communication Measurements Laboratory, 116 Greenwich St., New York City.*

Thunderbolt Counter

"An electric gadget that writes with lightning on a plastic slate." These are the opening words of maker's announcement of a new instrument which enables power company engineers to get an accurate record of the lightning strokes that hit their lines, thus showing the spots where protective devices are needed. Invented by Dr. Leo Finzi, a research engineer for manufacturer, this thunderbolt counter will also aid scientists seeking more accurate statistics on frequency of lightning strokes. Not much bigger than a playing card and weighing less than a whole deck, it has two strips of



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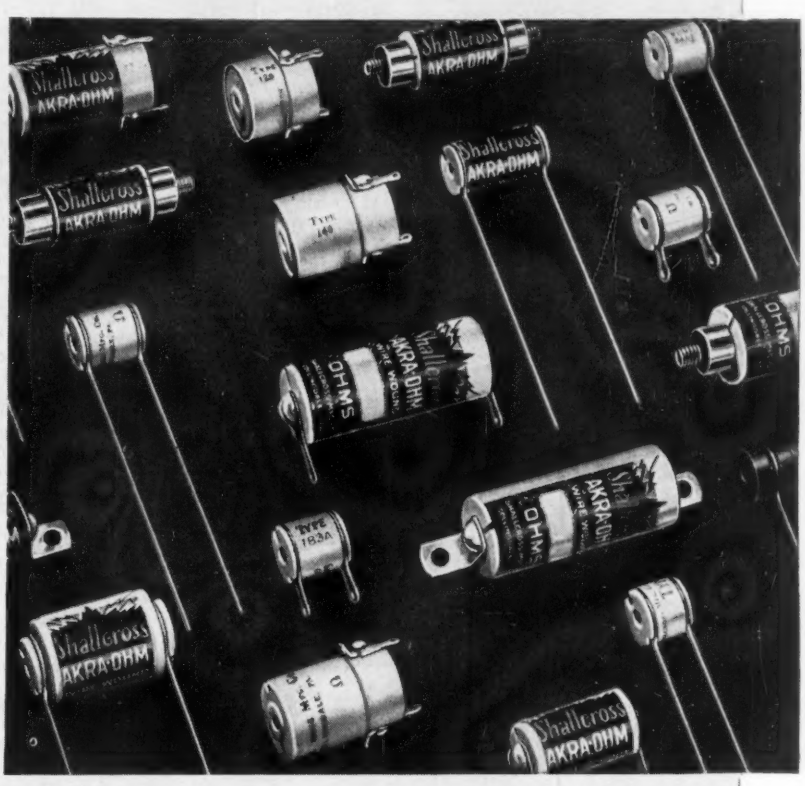

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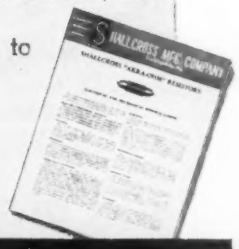

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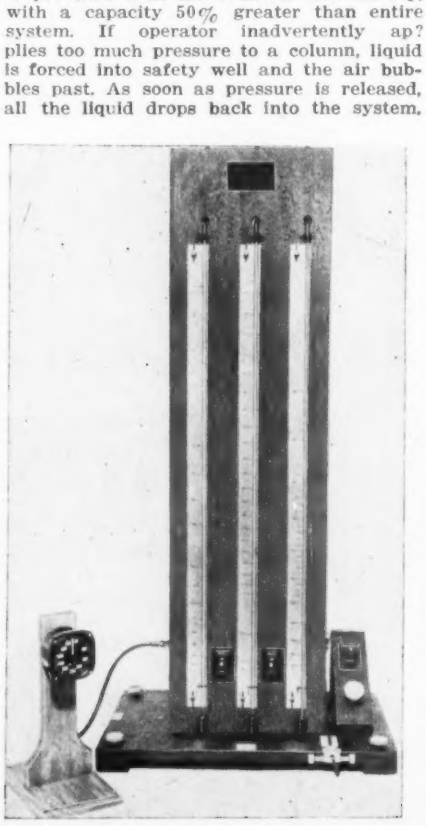
metal foil enclosed between two pieces of transparent plastic. One foil strip has a number of teeth cut in its edge, points of teeth being a few thousandths of an inch from straight edge of second strip. When lightning strikes a power line, a small part of the current is sidetracked into the counter and always picks out the easiest path—the tooth whose tip is closest to the straight-edged strip. As current leaps across this gap, spark scorches a black spot on clear plastic and burns away tip of tooth, so that next discharge will choose another path. "The counter never makes the error of jotting down two hits for a single thunderbolt, Dr. Finzi claims, because no two of the gaps between the two strips are ever exactly the same. Experiments with man-made lightning in the laboratories have shown that the lightning current always selects the easiest gap without hesitation. Though the difference in size between two gaps may be smaller than a ten-thousandth of an inch, there is always one path which is the easiest. As soon as the spark occurs, the voltage in the strip drops and another spark will not occur until lightning strikes again." New counter is easily fastened near bottom of a power line tower so black dots burned on it can be counted in a few seconds by a lineman or an engineer. It will keep a record of lightning strokes safely by-passed to ground by protective device at that point. When placed at towers along unguarded transmission lines it will disclose most-frequently-hit spots that require protection by arresters.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Manometer for Calibrating Pressure Instruments

"Type CTE-503 Precision Manometer" uses three liquids of different densities to obtain accuracy over a wide range of pressure and still keep meniscus at eye level. Designed as a standard for calibrating aircraft airspeed indicators, pressure gages and differential pressure gages, new manometer is suitable also for use in many aircraft and industrial test applications. Scales can be provided to read in miles per hour, knots, kilometers per hour, inches of water, inches of mercury, etc. Each column is provided with an overflow well at top, with a capacity 50% greater than entire system. If operator inadvertently applies too much pressure to a column, liquid is forced into safety well and the air bubbles past. As soon as pressure is released, all the liquid drops back into the system.



It is said that highest degree of accuracy obtainable has been combined with practical operating features. Each scale is provided with an easily adjustable zero setting handle. A specially-designed needle valve permits close adjustment and, in addition to this, a rubber tube passing through a set of rollers is employed for vernier adjustment. A simple on-and-off switch makes cycling easy.—*Kollsman Instrument Div. of Square D Co., 80-08 45th Ave., Elmhurst, N. Y.*

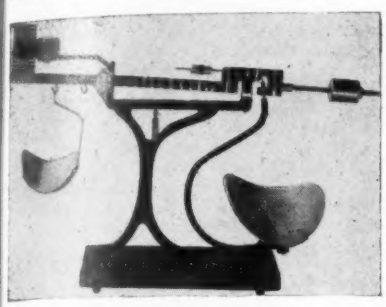
Speed Indicator

New "Jaeger Speed Indicator" utilizes well-known principle of adding the revolutions over a set period but is a new instrument produced in America for the first time. It consists of a watch movement combined with a revolution counter in such a way that revolutions are timed for exactly six seconds. This count, multiplied by ten, gives the revolutions in one minute, and scale is calibrated in r.p.m. Two models are available: No. 930 for all speeds up to 2000 r.p.m.; No. 935 for speeds up to 10,000 r.p.m. In low-speed instrument, one rev. of hand on large dial indicates 100 r.p.m. readable to 0.5 r.p.m. and one rev. of small

dial indicates to 1000 r.p.m. In the higher-speed instrument large dial is 0 to 1000 r.p.m. readable to 5 r.p.m. and small dial indicates to 10,000 r.p.m. In operation, instrument is held as shown and spingle—with suitable tip attached—is placed in center of shaft under test. Spindle will rotate, but hands will remain stationary. When ready to measure speed, press button and release it. Hands will now rotate and after six seconds will stop automatically at points which show average speed during the testing interval. Hands will remain in this position as long as desired. When button is pressed again, hands return to zero and watch is wound. Releasing button starts watch for next test; therefore, it is not necessary to return hands to zero until ready to make next test. Hands move only in a clockwise direction no matter which way spindle rotates. Automatic counting mechanism and indicating dials start about on or two seconds after starting button has been released, to let the watch come up to normal speed. After exactly six seconds of combined running, counting mechanism is automatically disconnected from spindle nd hands stop at positions which indicate average r.p.m. during the 6-sec. interval. Watch stops two or three seconds later. Thus readings can be repeated at intervals of ten seconds or more. Accuracy is conservatively guaranteed to be 0.5% of speeds above 5% of range. Spindle of instrument terminates in a pointed steel tip. Accessory tips include a separate rubber cone tip, a rubber funnel-shaped tip and a rubber-tired wheel 6" in circumference which gives f.p.m. readings. Case for indicator and accessories measures 3½" × 4⅞" × 1½". Combined weight of instrument, accessories and case is 11 oz.—*James G. Biddle Co., 1213 Arch St., Philadelphia 7, Pa.*

Ratio-method Small-parts Counter

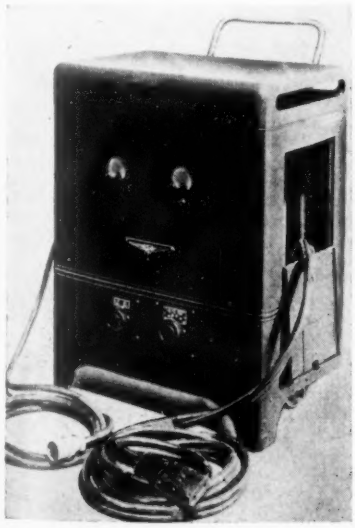
New "Micro-Counter" is a modified scale for counting large numbers of small parts "with speed and precision." Essentially, it consists of a ratio scale said to be built to



laboratory balance and accuracy. When scale is in balance, number of objects in counting pan bears a predetermined ratio to number of objects in sample pan. Since scale accuracy is 0.001 ounce (far less than individual weight of objects customarily counted) accuracy of count is limited only by any deviation from average weight—such deviation being minimized when plus and minus errors cancel each other according to laws of probability. In operation, parts to be counted are placed in counting pan and brought to balance with a counted number of parts in sample pan. A magnetic damper brings scale to a quick stop in spite of its 0.001-oz. sensitivity. A magnifying glass permits quick and accurate reading of balance indicator. New Micro-Counter is an obvious time-saver in dispensing small parts or in taking inventory; can be used also at counting stations to count pieces in bucket of large counting scales used for counting small parts.—*John Chatillon & Sons, 87 Cliff St., New York, 7, N. Y.*

Heavy-duty Rectifier for Airplane Equipment Tests

New "Amsco" rectifier is said to be "heavy enough to operate modern heavy-duty aircraft gun turrets." Extra-heavy inrush current required can be delivered while ample voltage is maintained to prevent drop-out of turret relays. "No-load" voltage is said to be within safe limit of any delicate electronic device or other electrical equipment in a plane. Rectifier provides all power needs for ground crew in testing planes of all sizes; provides voltage control with a "No-load" limit that may be set and locked to prevent tampering. Rectifying element is of "self-healing" dry disk magnesium-copper sulphide type. No bulbs or tubes are required. Bridge circuit is entirely insulated from primary. Three-



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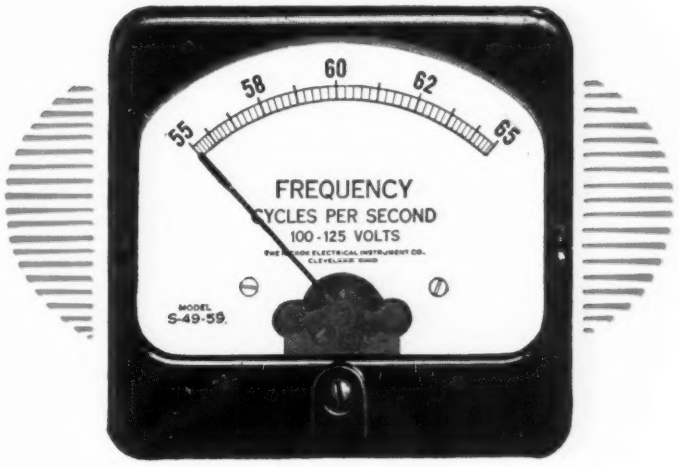

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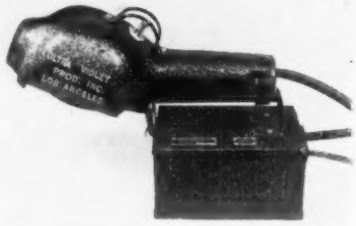

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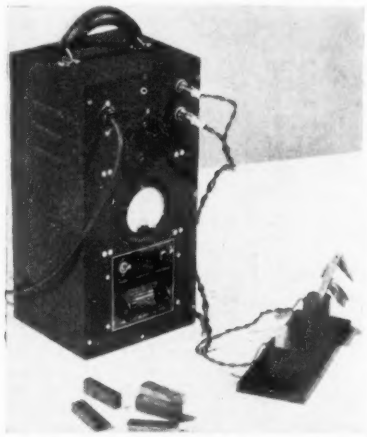
phase rectification guarantees smooth d-c. output, which can be quickly regulated by a rotary tap switch connected in primary circuit. Thermal protection is provided against overload or overheating. Fan guarantees air circulation. Cabinet is designed for all-weather use and provided with roomy side compartments for cables. A handle allows easy moving on 6" ball-bearing casters. Standard model has capacity of 20 to 28 volts at 200 amps with d-c. output starting inrush of 1200 amps; a 3-minute rating of 400 amps and continuous rating of 200. A-c. volts are 50/60 cycles, 3-phase, 460. Optional rectifying units of 20 to 28 volts and 10 to 14 volts are also available. —*Airplane Mfg. & Supply Corp., 6835 Lankershim Blvd., North Hollywood, Calif.*

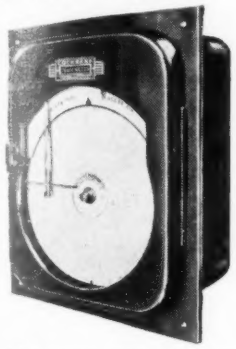
Magnetic Comparator

New magnetic comparator is for controlling quality of ferrous parts of same size and shape. Test is non-destructive when part to be tested is placed in a coil which has been balanced electrically against a standard part, comparator detects any difference in the two parts which changes the magnetic flux linking the coils surrounding them. Differences may be caused by wrong composition, improper heat treatment, hardness, size or other properties which affect magnetic flux within coil. Difference is shown as unbalance on comparator's zero-center indicating instrument. Comparator is said to be sufficiently sensitive to distinguish between steels whose hardness varies as little as two points Rockwell when hardness difference is the sole variable. It consists of a variable-voltage transformer, a sensitivity control rheostat, coarse and fine balance control rheostats and the required capacitors, all mounted in a portable steel case. Zero-center indicator, control knobs and necessary switches are located on front of panel. Test fixtures furnished with new comparator are two air-core coils; but where surface conditions permit and parts are too large for suitable coils, two gage heads can be furnished for contact measurements. These fixtures are interchangeable and both are equipped with flexible leads and connectors. Coils are available in a variety of sizes, thereby widening range of applications, since comparator attains its greatest sensitivity in testing when inside diameter of coil closely approximates that of part being tested. *Operation:* Two parts of same size and shape selected from a group of acceptable parts are placed within the coils where they are held in the same relative positions by wooden jigs (designed by user). Next, by adjusting sensitivity and coarse and fine balance, comparator's circuit is balanced to give a zero reading on indicator. One of the acceptable parts is then replaced by the part to be tested. Instantly the direct current provided by the full-wave rectification (which is essentially the difference in current between the coils) indicates difference between magnetic flux of acceptable part and that of part being tested. — *Special Products Div., General Electric Co., Schenectady, N. Y.*



Boiler Meter

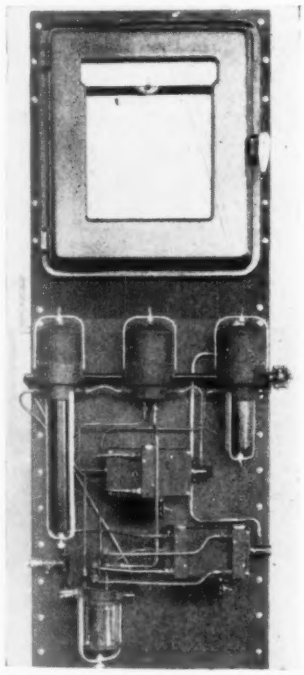
New "Boiler Ratio Meter" is of the steam-flow air-flow type. Several important advantages are claimed: Operator can establish relation of air supply to fuel supply



(measured by steam generated) most favorable to his particular operation by means of an easily adjustable cam in air flow mechanism. Quick and easy reading is provided by a red indicating pointer operating across a white 10" scale (no need to examine closely position of pens to determine whether air is excessive or insufficient, as the movement of pointer is 3 times as great as differences between pens). Steam flow mechanism is that of maker's standard electric flow meter, operating on null balance principle. Air flow mechanism is based on Hays slack diaphragm, equipped with an electric motor follow-up for ample power.—*Cochrane Corp., 17th St. and Allegheny Ave., Philadelphia 32, Pa.*

Gas Analyzer

New "4-Point Gas Analyser" continously records O_2, CO_2, CO and H_2 in combustion processes. Chemicals, fragile glassware and moving parts in the analyzing unit are



eliminated. Instrument operates directly from a-c. supply. Recorder may be located at any required distance from sampling point and instrument can be furnished with contacts for warning-signal or automatic-control circuits. Analysis principle is direct comparison of thermal conductance of sample with that of a reference gas, or comparison of thermal conductance of sample before and after chemical absorption or combustion. This principle permits units to be assembled to meet many special problems. In a typical unit a continuous gas

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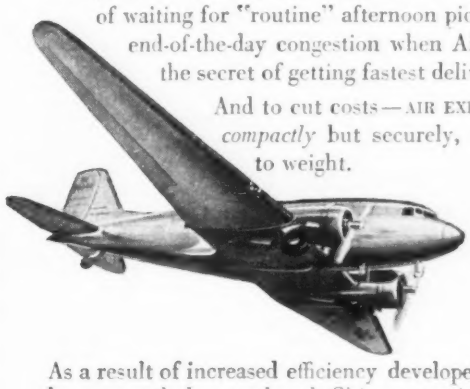

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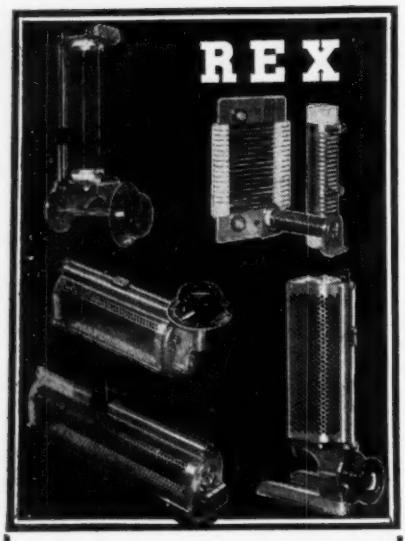

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Model 201 VIBROTEST

In a few moments the versatile VIBROTEST will reveal potential breakdown of insulation and forestall days of costly repair!

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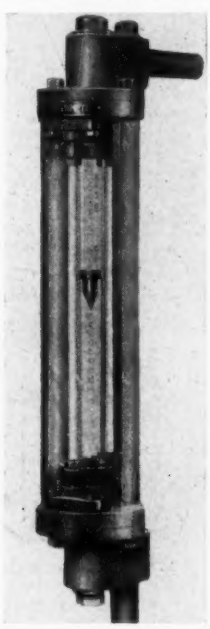
sample is drawn into the analyzer by means of a water bubble-aspirator which meters it as well as the air which may be required for combustion in the analysis procedure. In all applications, results are recorded directly without corrections or interpolation. Upkeep is said to be of a routine nature not requiring services of a technically-trained man. Recorder is automatically connected to circuit of each analysis cell in succession, duration of each connection being one minute. There is no additional time lag between points because gas sample flows continuously through all cells. Continuous record is provided on a 10" strip chart, with four different registrations (one for each gas) shown by different colors and numbers.—*Cambridge Instrument Co., Inc., 3732 Grand Central Terminal, New York City.*

50-ampere Relay

New solenoid type 50-amp. aircraft relay is said to be characterized by light weight, rigid construction and high operating efficiency. This relay has been developed primarily for the aviation field: controlling circuits for landing lights, fuel pumps, gun firing controls, etc., but it is said to have many civilian applications as well. Weight is below 0.6 lb. It will withstand a surge load of 400 amps. without injury to contacts; its leads are "fully protected" and it will withstand vibration (total excursion 1/16" in any direction) of 5 to 55 cycles per second.—*The Hart Mfg. Co., Hamilton St., Hartford, Conn.*

"Universal" Rotameters

New "Universal Rotameters" embody design refinements, among them: While one-piece frame construction has been retained, new type universal end-fittings provide for 25 different piping hook-ups. Fittings can be turned to permit horizontal connections exactly 90° apart (all Rotameters are provided with connections for installations in vertical pipe lines). Tubes may be cleaned without taking meter or tube from pipe line, even with vertical connections. Streamlined surfaces easier to clean inside and out. Exceptionally rigid frame giving adequate support to the glass tube in event of pipe distortion. Plastic protective tube fitted



over standard glass tube when desired. Outlet safety head permits rotor to rise above top of glass tube to prevent breakage from sudden flow surges. It is said that since accurately cut slots in rotor head cause it to spin in the fluid, rotor remains in center of fluid stream so that there is no friction or wear. Removable rotor stops—top and bottom—are provided. All tubes are ma

chine-made, stress-relieved and polariscope-tested. Tubes and rotors for each size Rotameter are standard and interchangeable. Spacing of calibration marks is practically uniform over entire length of tube, which assures accuracy even at flow rates as low as 1/10 of maximum. Heavy-wall glass metering tube is said to be capable of withstanding high pressures and is highly resistant to wear, corrosion and thermal shock. Rotors can be made of any suitable material, including glass. End fittings for the ½" to 2" standard Rotameters for severe corrosive service can be furnished on special order. Availability: Most requirements can be answered by factory assembly of tubes, rotors, frames and end fittings into complete units and, since these parts are stocked in many sizes, shipment can be made on short notice.—*Schutte & Koerting Co., 12th & Thompson Sts., Philadelphia 22, Pa.*

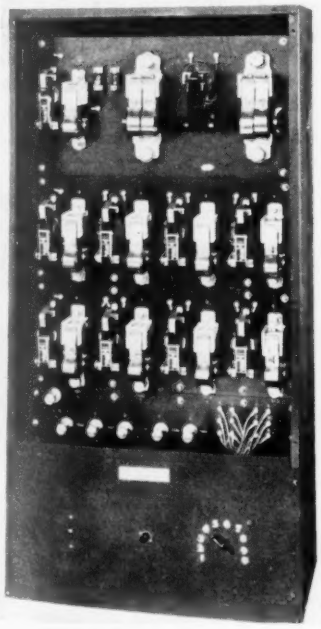
Tube Cutter

New "No. 212-F Aviation Tube Cutter" is said to be scientifically designed to make the clean, right angle cuts essential to perfect AN-type flares. It cuts aluminum,

aluminum alloy, copper, brass or steel aircraft tubing in sizes from ⅛" to 1-⅛" outside diameter. Tubing rests against two rollers, facilitating operations and preventing galling or rubbing. A special flare cut-off groove in rollers enables operator to remove a damaged flare with minimum waste and it is said, frequently eliminates replacing the tubing. A convenient reamer for removing burrs is a part of the tool.—*The Imperial Brass Mfg. Co., 1200 W. Harrison St., Chicago 7, Ill.*

Magnetic Voltage Selector

New Magnetic Voltage Selector was developed for a new electroplating process, for anodizing aluminum on a.c., but is said to have many other uses where like appli-



cations of current are required. Selector is for transferring in steps from 2 to 40 volts. Arrangement is such that when transferring, main contact opens before secondary contact opens, and closes after secondary contact is closed. Arcing is thus effectually eliminated. New unit embodies automatic

SOLDERING DANGERS VOIDED WITH "COPROX" RECTIFIERS

● Assembly is simplified, and overheating virtually eliminated, by lead wires soldered in advance to contacts on the three "Coprox" (copper oxide) rectifiers shown at the bottom of the panel below. BX-22.3 contacts are solder-filled in advance. The BX-100 has a nut-and-bolt contact.

Other "Coprox" features include gold coating on the positive contact surface of standard copper oxide "pellets" . . . high leakage and low forward resistance . . . adaptable mountings . . . conservative ratings and high test standards.

Broad experience with rectifier applications, and with circuit design and manufacturing problems, prepares Bradley to accept and meet unusual specifications for "Coprox" rectifiers. Ask for details.

BX-22.3 Double bridge rectifier with current and temperature-current characteristics balanced to better than 1% over a range of −40°C to +70°C. Rated up to 4.5 volts A.C., 3 volts D.C., 5 milliamperes D.C.

BX-100 Center tap, full wave rectifier. Completely enclosed in Bakelite. Low capacitance. Rectifies high frequency current. Rated up to 4.5 volts A.C., 3.0 volts D.C., 500 microamperes D.C.

BX-22.5 Single half-wave rectifier rated up to 4.5 volts A.C., 3.0 volts D.C., 2.5 milliamperes D.C.

BX-22.2 Full wave rectifier rated up to 4.5 volts A.C., 3.0 volts D.C., 5 milliamperes D.C.

BX-22.4 Double half-wave rectifier rated up to 4.5 volts A.C., 3.0 volts D.C., 2.5 milliamperes D.C.

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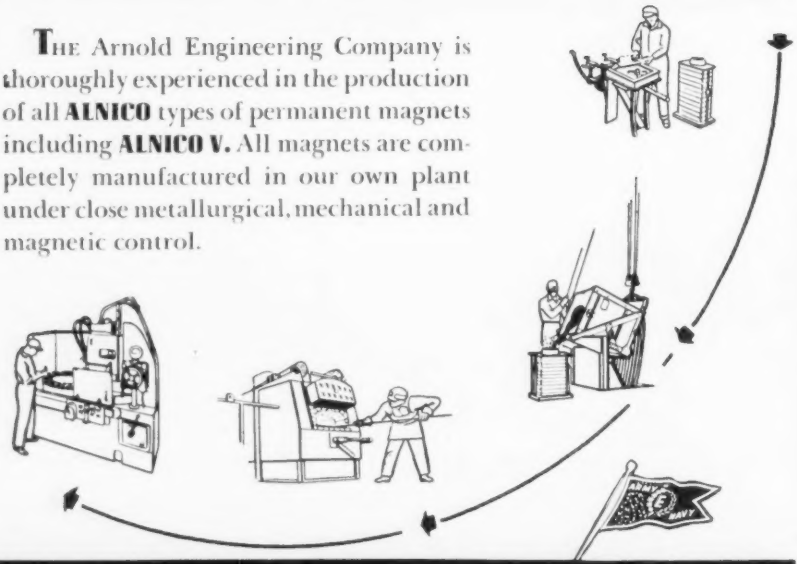

THE ARNOLD ENGINEERING COMPANY

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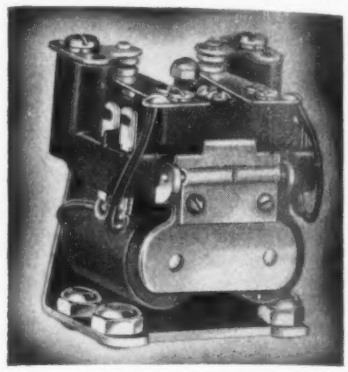
main magnetic contacts, and automati main switch contacts for nine positions a 2½ volt intervals, from 2 to 40 volts. A illustration shows, unit is convenienti paneled for ready accessibility and com pactly cased.—*Zenith Electric Company, 15 West Walton St., Chicago 10, Illinois.*

Dual-coil Relay

New "Model BOY" is announced as dual-coil small power relay with sensitiv (½ watt) operation. It is said that doubl coil construction sharply reduces power con sumption (for satisfactory operation) ove single-coil relays of equal load capacity thus making this type of unit suitable fo use in limited-current plate-circuit applica



tions. In addition, the two coils may be con nected in series for operation at one voltag and in parallel for a second voltage; or on coil can be used for operation while th other is used for holding. New relay is rug gedly built to withstand 10-*G* acceleration meets Army, Navy and CAA specification Dimensions 1⅝" × 1¾" × 1½"; weigh five ounces.—*Allied Control Co., Inc., 2 Eas End Ave., New York City 21, N. Y.*

Electron-tube Interelectrode Capacitance Meter

New "Model 37 Interelectrode Capacity Meter" provides direct measurements o vacuum-tube interelectrode capacitances o a production basis, may be used by un skilled personnel. Micromicrofarads are read directly when a tube is plugged int wholly shielded measuring circuit incorp orated in instrument. Five-step range is from 0.001 to 100.0 mmfd with accuracy of 5% or better on all steps. On the lowes range, increments as low as 0.00001 mmfd may be used. Measurement is made at radio frequency in a crystal-controlled ci

cuit having both primary and secondar voltages automatically regulated for max mum operating stability. Connector bas accepts adapters for tubes up to 8-pin an provides for connection of co-axial cable to any pair of elements whose capacitanc is to be measured. "Universal" shield fur nished with instrument accommodates tube up to 2⅝" diam. and 4¾" high; standar RMA shields specified for various tub types may also be used. Special shield for unusual tube types can be supplied Range and operating characteristics of t

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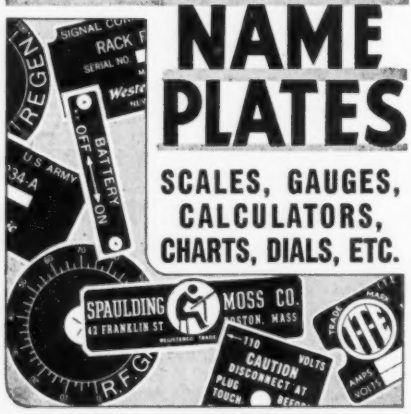

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strument are said to permit its use wherever rapid, accurate measurement of low capacitances is required. Special adapters, constructed to suit application, may be attached to connector base for measurements not involving vacuum tubes—*Technical Apparatus Co., 1171 Tremont St., Boston 20, Mass.*

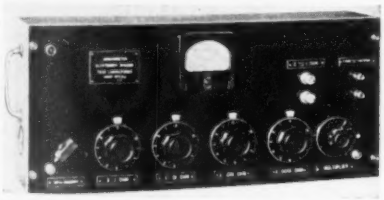
Test Stand for Propeller Governors

New test stand for Curtiss Electric propeller governors produces flight-condition vibration on governor being tested, includes an automatic control unit which allows

governor under test to control speed of driving unit. A selector switch on instrument panel enables operator to choose automatic or manual operation. Two lamps indicate opening and closing of the inc. and dec. r.p.m. governor contacts during operation; another lamp indicates any grounded circuit in the governor. Drive is 3 h.p. variable-speed unit with a range of 900 to 3600 r.p.m. (standard: 220-v. a.c. 60-cycle, 3-phase electric motor. Other voltage on request). Chrono-tachometer unit on panel consists of electric clock, revolution counter and tachometer. Power is supplied to test stand from outside source and control of stand as well as speed and direction of its motor is through push buttons.—*Airplane Mfg. & Supply Corp., Mfg. Div., 6053 Lankershim Blvd., North Hollywood, Calif.*

A-c. Bridge for Resistances and Impedances

New "Type G-710 Microhmmeter" is basically an a-c. bridge but is said to be "a very special and greatly improved a-c. bridge which will do things never before



thought possible. Due to the great sensitivity and large output it is possible to use this circuit for many purposes requiring recording or controlling apparatus such as temperature control, moisture control, pressure control, etc." Instrument is a-c. operated, is capable of measuring from 0.0001 ohm to one megohm. Readings are taken from a decade and the null indicator is of the pointer type. On all ranges, Microhmmeter requires but a few tenths of a milliwatt through the resistance being measured. Measuring voltage is 60-cycle a-c. Pure resistances may be read directly as ohms; impedances are measured by comparison, changes as low as 0.01% being indicated. Low current at terminals makes it possible

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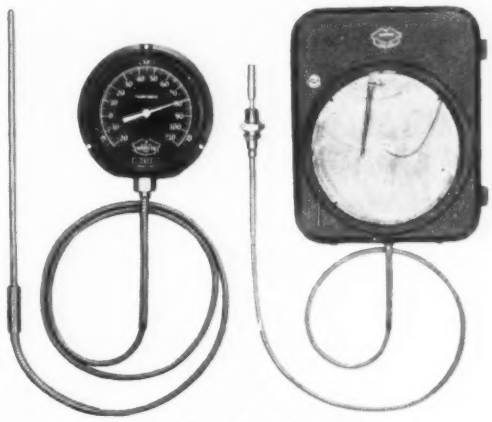
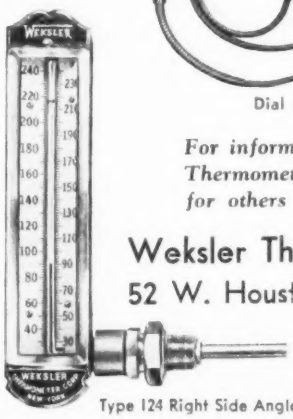
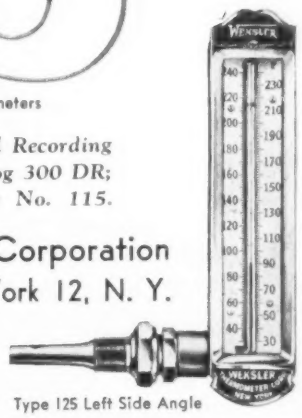


Dial and Recording Thermometers



Type 124 Right Side Angle



Type 125 Left Side Angle

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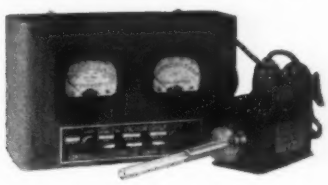

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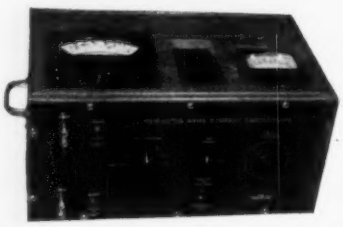

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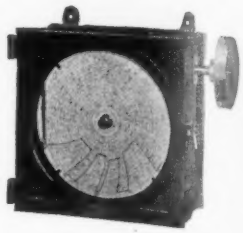
to measure contact resistance in relays, switches, joints, bondings, etc., without changing contact conditions by heat. No current terminals are required as used in the Kelvin bridge, but high-current effect may be studied by applying up to 5 amperes, in series with resistance under test. This will not change the readings except for the internal resistance of the d-c. source (0-1 ohm range). Delicate low resistances such as instrument armatures, fine filaments, small coils, etc., may be measured without the effects of heating. Conductances of solutions are measured to 2% accuracy. Changes of 0.01% of total resistance are read without effects of polarization. Any d.c. present from dissimilar metals will not affect readings. Ranges: 0 to 1.111 ohms in steps of 0.0001 ohm; 0.01 to 111.1 (steps 0.01); 1.0 to 11,110 (steps 1.0); 100 to 1,111,000 (steps 100). Sensitivity: Variable from zero to one part in 10,000. Accuracy 2% on 0 to 1.111 ohm range; 0.5% 1 to 1,111.000 ohms; better tolerance to order. Stability: 10% change in line voltage produces a 0.01% change in readings; no inherent drift. Output: a 9.5-0-0.5 ma. d-c. galvanometer is used as a null indicator; there is sufficient d-c. output to drive a recorder or sensitive relay. Size: 18½" × 8½" × 6". Weight: 25 lbs.—*Tech Laboratories, 7 Lincoln St., Jersey City 7, N. J.*

Airplane Engine Horsepower Indicator

New Horsepower Indicator (developed by makers in conjunction with N.A.C.A. and leading U. S. radial engine manufacturers) provides direct readings of both net horse-

power output and brake mean effective pressure on one dial, obviates need of flight engineer making numerous calculations (with consequent possibility of error) and makes it easy to see effects of adjustments to controls on output of engine. Pointer gives operator a continuous indication of b.m.e.p. at all times on inner dial and a reading of brake horsepower on outer dial when correct r.p.m. is set on subdial (dark sector visible just below pointer). New instrument operates from hydraulic type torque balance units which function from planetary propeller reduction gear (available on all large U. S. radial aircraft engines), thus gives operator an indication of net shaft horsepower output not obtainable in any other way, it is said. Having brake horsepower and b.m.e.p. directly indicated in this manner is advantageous because this must otherwise be laboriously calculated by use of engine output curves and readings of manifold pressure, r.p.m., altitude, outside air temperature, humidity and an estimate of power used by auxiliaries and friction of engine. Moreover it is said, with new indicator, operator also receives a quick indication of motor trouble such as a fouled spark plug which might not be apparent in any other way. New instrument is available in both remote and direct indicating types. — *Kollsman Instrument Div. Square D Co., 80-08 45th Ave., Elmhurst, N. Y.*

Amthor



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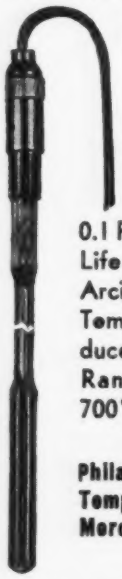

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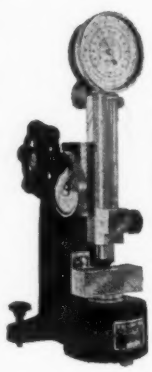

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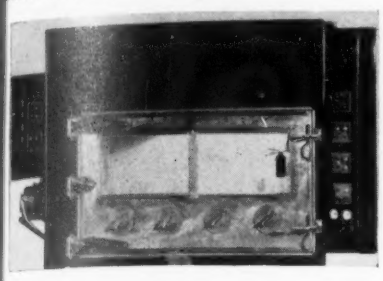
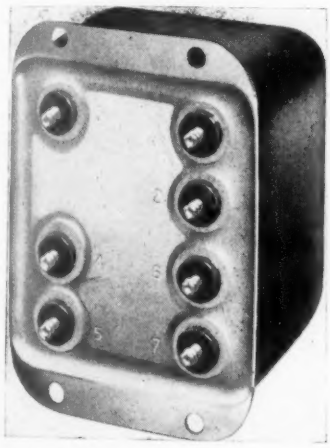
New "Model RTC-1" is an improved type of test chamber for high and low temperatures. (For description of standard features of previous models see *Instruments*, Sept. 1942, page 385; July 1943, page 458; Sept. 1943, page 578.) Improved cabinet may be obtained with four individually operated plugs in lower panel of door for ready access to interior. A turn of handle opens plug. Hand may be inserted through an insulated passage and an instrument or a part being tested can be adjusted without removing it or disturbing others. No need of opening the whole door. Machine is completely automatic, can produce desired temperature between — 70°C. and 258.8°C.—*American Coils, Inc., 27 Lexington St., Newark, N. J.*



Sealed Transformer

New "Type S" hermetically sealed transformer is designed for use in all theatres of war operation and on all types of equipment, was recently approved by Navy, is said to be of extremely rugged construction. Case is of cold-drawn copper-cadmium-plated steel. Terminal is molded into a plastic block which has a metal flange molded into its periphery. This flange is then soldered into the case. New construction is said to offer great flexibility in number and arrangement of terminals. "Vac-sealing" impregnation process is said to assure "absolute impregnation without solvents or other deleterious material present inside the coil." New transformer is produced "in any desired size or capacity to customers' specification."—*Peerless Electrical Products Co., 6920 McKinley Ave., Los Angeles 1, Calif.*



Electric Furnace

New "Model GRP" electric furnace, for laboratories or for heat-treating, operates continuously at temperatures up to 1500°F. and intermittently to 1850°F. Heat selection is through heavy-duty rheostat and switch with monel metal contacts. Ranges: Low 70° to 400°, medium 400° to 800°, high 800° to 1500°F. Operates on a.c. or d.c. and is available in either 115- or 230-volt units. Maximum power consumption 1200 watts. Heating to maximum tempera-

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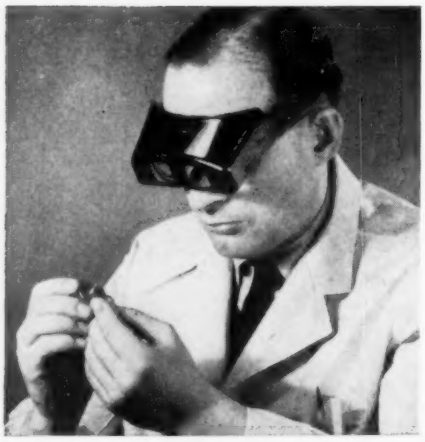

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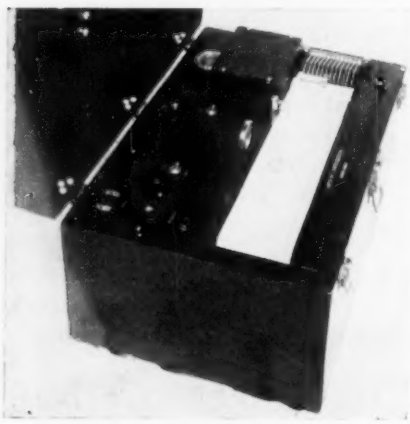

GARCEAU CHRONOGRAPH

Eleven Recording Channels
One Timing Channel

Through an inertialess electrical recording system, this Garceau Chronograph provides means of measuring without error the length of time an electric current flows. Tape can be withdrawn manually, to allow inspection of recent records, with provision for independently actuated electrical re-wind of used tape.

Tape speed is 20 centimeters per second. Timing channel prints a row of dots spaced at 1/60 second intervals.

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Holliston, Massachusetts, U. S. A.
Makers of the Garceau Electroencephalograph

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By using PYRO, a self-contained, DIRECT READING, sturdy unit made to stand rough use. It is absolutely accurate and dependable, and quickly pays for itself.

Unique construction enables operator to rapidly determine temperature even on minute spots, fast moving objects, or smallest stream; no correction charts, no accessories, no maintenance expense. Special "FOUNDRY TYPE" and "Universal TRIPLE RANGE" have, in addition to standard calibrated range, a red correction scale determining TRUE SPOUT and POURING TEMPERATURES of molten iron and steel when measured in the open.

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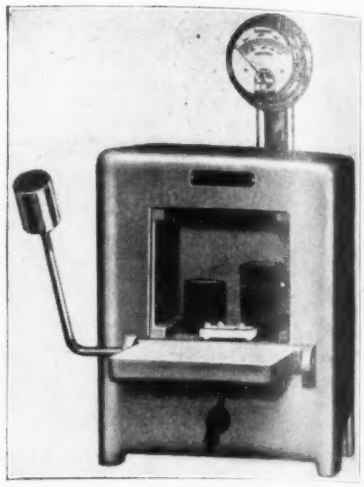


tures takes but 30 minutes. Nichrome heating element is embedded in refractory, minimizing oxidation. Entire heating element is used over full heating range and covers four sides of muffle chamber, eliminating cold spots. Reinforced muffle unit of exclusive new design is said to practically eliminate cracking. Furnace is available with indicating pyrometer calibrated in both C. and F. construction features. One-piece body casting and counterbalanced door which forms convenient loading platform when open. Inside dimensions 4" wide, 3¾" high, 3¾" deep.—*Thermo Electric Mfg. Co., 480 W. Locust St., Dubuque, Iowa.*

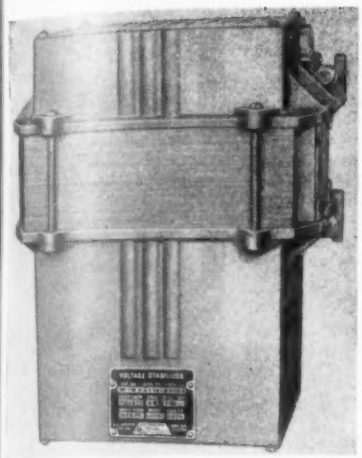
Snap Gage Stand

New stand supports a roll thread snap gage in an easy working position, minimizes operator fatigue and enhances inspection accuracy. Stand firmly retains gage by means of an Allen head socket screw and in larger types (Model GSA) by an additional bearing plate which engages wide machine pads on Vard snap gage frame. New stands are made in two types:

"Model GSC," 4½" long, 3" wide, 3¼" high weighs 2 lbs.; "Model GSA" is 6⅝" long, 3½" wide, 3½" high, weighs 5 lbs. handles gages of sizes up to 13" work diam. Stands are made of a heavy cast metal, coated with wrinkle-finish baked enamel, mounted on heavy felt pads.—*Vard Inc., 2961 E. Colorado Blvd., Pasadena 8, Calif.*

Voltage Stabilizers

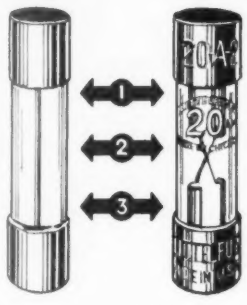
New voltage stabilizers are announced in ratings from 25 to 2000 watts, for 50-cycle single-phase inputs of 95-130 volts and 190-260 volts (outputs 115 and 220/230 respectively). Output stability is ± 0.5% and is accomplished within two cycles. New of two transformers with primaries in stabilizer has no moving parts: it consists series, the one which operates at the higher saturation being partly resonated by a



apacitor. Secondaries are connected in eries opposed. Design is such that voltages dd up vertically, producing desired output anges compensating for differences of in-ividual voltages. Since partial resonance a requisite design feature, new stabilizers e sensitive to frequency changes: output oltage will vary in the same direction and 4 times the percentage change in fre-uency, over a range of 5% of normal requency but stabilization will be within 0.5% of output voltage established by requency. Overloading does no harm to nit, this characteristic being especially esirable in operation of vacuum tubes hich tend to draw heavy filament current ntil tube operating temperature is reached. tabilizers are available in "endbell" model illustrated), cased models and uncased models. Weights range from 8 lbs. (30-watt tabilizer) to 220 lbs. (200-watt).—*Raytheon Mfg. Co., 100 Willow St., Waltham, Mass.*

Compare **LITTELFUSE** with an **ORDINARY FUSE**

ORDINARY FUSE LITTELFUSE



1 Cap forced or cemented on.

2 No reinforcement of fuse element.

3 Unprotected against contraction and expansion.

1 LOCKED CAP ASSEMBLY (Patented).

2 Element twisted at 90° against vibration.

3 "Gooseneck" takes up contraction and expansion.

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Center Scope Brings Optical Precision to Machine Shop Operations

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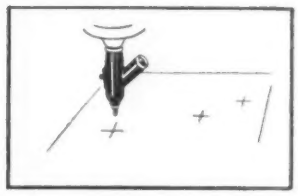
The Center Scope's easy accuracy eliminates many human errors, as the operator can see just what the cutting tool will do before it is actually fed into the work. It increases production, improves efficiency and prevents spoilage. There is no pressure on the work piece nor is it subject to wear or changes in temperature—for the Center Scope never touches the layout.

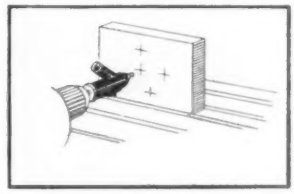
The Center Scope enables the operator to easily and quickly locate edges to a spindle axis, set-up faster and compensate for run-out. It saves vital hours in checking, inspecting and measuring when mechanical methods and tools are impossible to use. Its 45 x magnification allows operator to see ".001" and requires no technical knowledge or training to operate.

While there is nothing particularly new or ingenious about Wrigley's Spearmint gum, it is proving useful to millions of people in many new ways. Workers in war plants everywhere have found it helps keep them alert and relieves nervous tension and dry mouth while they are on the job.

You can get complete information from the Center Scope Instrument Company, 351 S. LaBrea Ave., Los Angeles, Calif., or Kearney & Trecker Products Corporation, Milwaukee, Wis.



ON A VERTICAL MILL—locating and centering height gauge or size block layouts. Permits jig borer accuracy on more machines.



ON A HORIZONTAL MILL—the ability to center a layout, edge block or rotary table plug while spindle is running. Permits quick and easy set-up for high precision work.

Y-109

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INSTRUMENT SOCIETIES CALENDAR

City	Society and Secretary		Date	Place	Subject	Speaker
Atlanta	Georgia Society for Measurement & Control	Roger W. Allen, 376 Nelson St., S.W., Atlanta				
Baltimore	Baltimore Industrial Instrumentation Society	C. B. Willnecker, 6732 Danville Ave., Dundalk, Md.	Apr. 21(D)	Enoch Pratt Free Library	Flowmeter Maint'ce and discuss'n of liquid level gages	Louis Gess, Brown Instrument Co.
Chicago	Chicago Society for Measurement & Control	Carl Hope, 2626 W. 31st Blvd., Chicago	May 1(B)	M&M Club, Merchandise Mart	Electrical Recording Instruments	R. J. Kryter, Esterline-Angus Co.
Cleveland	Cleveland Instrumentation Society	F. G. Meulenberg, DuPont Exp'l Lab.				
Gulf Coast	Gulf Coast Instrument Maintenance Men's Ass'n	T. H. Pierson, 3030 Roberts St., Beaumont, Tex.				
Hartford	Hartford Society for Measurement & Control	Stephen J. Zelle, Whitney Chain & Mfg. Co., Hartford, Conn.				
Newark	New Jersey Society for Measurement & Control	N. E. Chance, 14 Glen Oakes Ave., Summit, N. J.	May 2(B)	Essex House	Trend in Use of Laboratory Instruments in the Plant	C. E. Ohlheiser, Amer. Instrument Co.
			June 6(B)	Essex House	Electronic Pyrometry	C. O. Fairchild, C. J. Tagliabue Mfg. Co.
New York	New York Society for Measurement & Control	H. R. Kalbfleisch, 114-35 No. Blvd., Flushing, N. Y.	Apr. 25(B)	Building Trades Emp. Ass'n, 2 Park Ave.	New Optical Tools for Research	Dr. W. B. Rayton, Bausch & Lomb Optical Co.
N. Indiana	Northern Indiana Soc. Measurement & Control	R. W. Schreiner, 4 Waltham St. Calumet City, Illinois				
Philadelphia	Philadelphia Society for Instrumentation	J. E. Gambrill, 1317 Spruce St.	April 19(B)	Engineers Club	Influence of Line Drop on Valve Characteristics	C. E. Mason, Mason-Neilan Regulator Co.
			May 17(B)	Engineers Club	Instal'n and Oper'n of Differential Flowmeters	L. K. Spink, Foxboro Co.
Pittsburgh	American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pgh.	April 24(B)	Roosevelt Hotel	Electronic Measurement & Control	S. L. Burgwin, Westinghouse Elec. & Mfg. Co.
			May 22(B)	Roosevelt Hotel	Air-operated Control	J. N. Swarr, Bristol Co.
St. Louis	St. Louis Society for Instrumentation	Gus Holubeck, Union Electric Co., Venice, Ill.				
Toronto	Canadian Society for Measurement & Control	T. C. Agnew, Minneapolis-Honeywell Reg. Co., Toronto				
Washington		(being organized, see news note)	Apr. 18(D)	Interior Dep't Auditorium	Spec'l Appl'ns of Cathode-ray Oscilloscope	P. S. Christaldi, Ch. Eng., Allen DuMont abs.

(A)Meeting at 7:30, no dinner. (B)Dinner at 6:30, meeting at 8. (C) Dinner at 7, meeting at 8. (D)Meeting at 8, no dinner.

BALTIMORE

The March 17 meeting of the Baltimore Industrial Instrumentation Society was held at the Enoch Pratt Free Library, Cathedral, Franklin and Mulberry Streets, Baltimore, at 8 p.m. We had an attendance of 28 members and guests.

Mr. F. C. Phillips, Glenn L. Martin Co., Middle River, Md., addressed the society on "The Use of Instruments in Performance Testing of Aircraft." A lively question period followed the lecture.

—CARL B. WILLNECKER

CHICAGO

At the February 7 meeting, in Huyler's Restaurant, an overflow crowd was on hand to welcome the speaker of the evening, Dr. D. J. Bergman, of the Universal Oil Products Co., whose subject, "Liquid Level Controls,' was of interest to a great majority of the crowd, not only because of the subject matter but because of the relatively informal manner of presentation. He touched on the historical development of industrial liquid level controls as well as discussing some of the more common applications. He particularly emphasized the relationship of capacity to the type of control to be applied and the results to be expected.

At the March 6 meeting, held at the Merchant & Manufacturers' Club in the Merchandise Mart, the speaker was Mr. N. K. Koebel of the Lindberg Engineering Co., whose subject was "Furnaces with Controlled Atmosphere." Mr. Koebel described the two instruments normally used for determining the condition of furnace atmospheres: the thermal conductivity type and the gas density type. He pointed out that neither of these instruments took cognizance of water vapor. He explained the difficulty of designing an instrument which would recognize water vapor, but at the same time emphasized the need of having this information. He recommended research on the part of instrument companies toward development of an instrument for this function.

The largest crowd of the current season enjoyed Mr. Koebel's talk as well as the subsequent movie on heat treating offered by the Lindberg Heat Treating Co.

Secretary Carl Hope has been inducted and has been replaced for the duration by A. J. Butler (also of International Harvester).

—J. A. RIGGS

NEWARK

Nelson E. Chance

Nelson E. Chance, Acting Secretary and charter member of the Society for Measurement and Control (New Jersey), died on March 12, following a short illness.

His passing was a severe shock to his many friends and business associates, and will be keenly felt by the Society, in whose formation he actively participated.

Mr. Chance had been with the Brown Instrument Co. for 22 years. The earnier years were spent in the Southwest oil areas, and for the last eight years he was manager of Brown's New York area. One of the best-known of the engineering representatives, he was widely known in the petroleum industry, the instrument industry, and allied fields in New York and the Southwest.

Mr. Chance was born at Dividing Creek, N. J., and was a graduate of Bucknell University. He is survived by his widow, Martha L. Chance and his two daughters, Martha Jeanne and Betty Jane.

—H. F. MOORE

At the April 4 meeting, Mr. Kermit Fischer, president of the Fischer & Porter Co., spoke on "The Rotameter and Its Secrets" before more than fifty interested listeners. Mr. Fischer started by describing a rotameter for the benefit of anyone not familiar with it. He then traced its development from the earliest patent descriptions to the latest models. In this way he showed how various characteristics, such as reaction to viscosity and density, can be designed into the meter. One interesting example was the use of two rotameters in series, having different reactions to viscosity, as a continuous viscosimeter.

—R. H. GRAY

NEW YORK

The February meeting was held at the Building Trades Employers Association at 2 Park Avenue. The speaker was Dr. R. M. Sutton of Haverford College whose topic was "The Long and Short of Wave-length Measurement." His speech was based mostly on pure physical science. He handled exceptionally well a wide field of wave-length measurements. Wave-length was defined and demonstrated with coil springs and whistles. Then followed a discussion of sound, light, x-rays and radio measurements. Various parts were also explained with the aid of slides. New and recent methods used in measurements were explained along with some recent applications of x-rays to determine crystal structures. Very few references were made to the use of mathematics throughout the talk. During the discussion period many questions were expertly answered by Dr. Sutton.

The door-prize, a copy of "Maintenance and Servicing of Electrical Instruments," donated by the Instruments Publishing Co., was won by U. J. Sheppard of the U. S. Navy Yard, Charleston, N. C.

The March 28th meeting had an attendance of eighty-two for the dinner. There over a hundred were present for the meeting which took all the available chairs with the overflow crowd filling the doorway. Dr. P. G. Weiller of Kollsman Instrument Div. of Square D Co. spoke on "Electronics —Servant or Fad?"—a question, which Dr. Weiller discussed and the lecture was unique in that it pointed out the advantages, pitfalls, and other facts that the experimenter must consider before entering the field. This was further amplified by the speaker's own experiences which reflected his years of engineering in this field. Following the talk, the audience gathered around the big exhibit of instruments while they were demonstrated and explained. Everyone attending the meeting had been given a new slant on the outlook of electronics and its future.

—H. R. KALBFLEISCH

NORTHERN INDIANA SOCIETY FOR MEASUREMENT AND CONTROL

EDUCATION—FRATERNITY—DEMOCRACY

Our March meeting was held Friday the 10th at the Lake Hotel in Gary. After a fine dinner, Mr. C. A. Maynard, engineer from the Indiana Steel Products Co., topped

of a fine evening with his speech on "The Development of the Permanent Magnet and Its Application to Modern Devices."

Mr. Maynard gave us the story of the magnet from the time the magnetic particles were found in the earth, up to the present-day magnets used in modern devices. The process of manufacturing and calibrating the magnet was given very fully and, last but not least, how to recalibrate and the care that should be given a magnet was explained thoroughly. —R. W. SCHREINER

PHILADELPHIA

At the March 15 meeting we were privileged to hear Mr. J. G. Ziegler of the Taylor Instrument Companies cover very thoroughly the subject of "Adjustment of Rate Responses." Mr. Ziegler pointed out that most industrial processes were multicapacity processes and that the analysis of the instrumentation problem was quite complicated. Mr. Ziegler pointed out how it was possible to calculate the "sensitivity" from the period of oscillation from which it was further possible to calculate the "reset rate."

Most of the members in attendance felt that they would like to investigate further the ideas covered in Mr. Ziegler's talk, and asked for reprints of his published articles.

There was a total of 34 in attendance at the dinner, and a total of 92 at the meeting. —J. E. GAMBRILL

WASHINGTON, D. C.

[Excerpts from a letter to the Editor of *Instruments*]

You will be pleased to learn that an attempt is being made to organize an Instruments Society in Washington, the home of the Bureau of Standards, Naval Research Laboratory, Naval Gun Factory, Weather Bureau, D. W. Taylor Model Basin, Coast and Geodetic Survey, Carnegie Institution, Smithsonian Institution, Johns Hopkins Laboratory of Applied Physics, Naval Observatory, War, Navy and Agriculture Departments and many other agencies employing engineers and scientists.

In the past two years I have taught at George Washington University eight fifteen-week classes of a course on "Engineering Instruments" and three classes of an "Aircraft Instruments" course. The total registration approximated 300 and 150 students, respectively. . . . It was inevitable . . . that I should discuss . . . the need for an Instruments Society in Washington. The reaction was always favorable. . . .

The initial meeting, at which it is hoped a temporary organization of the society may be effected, will be held Tuesday, April 18 at 8:00 p.m. in the Interior Department Auditorium. . . . Dr. P. S. Christaldi, Chief Engineer of the Allen B. DuMont Laboratories, Inc., will speak on "The Cathode-ray Oscilloscope." . . .

. . . Plans are to hold a second meeting in May before recessing for the summer. . . .

Because of the nature of the potential membership, I visualize the society as being mainly concerned with the theory, description and use of engineering and scientific instruments as contrasted with the maintenance aspect. . . .

. . . Those desiring further information regarding the society or wishing to be placed on the mailing list should contact me at 2400 S St., SE, Washington, or by phone at TRinidad 3362.

—RICHARD C. DARNELL

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS

The Spring Meeting of the Society for Experimental Stress Analysis, including a Symposium on Residual Stresses, their Measurement, and Effects, will be held at the Hotel Statler, Boston 17, Mass., May 18, 19, 20, 1944.

Inquiries should be addressed to Society for Experimental Stress Analysis, P. O. Box 168, Cambridge 39, Massachusetts.

—W. M. MURRAY

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(Appeared serially in *Instruments* from August 1941 to June 1943

By JAMES SPENCER

In charge of Instrument and Relay Department, Meter Division, Westinghouse Elec. & Mfg. Co., Newark, N.J.

Edited by

M. F. BEHAR, Editor of *Instruments*

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Manufacturers' New Literature

In this department we report ALL pieces of new literature pertaining to Instrumentation received from the manufacturers. To assist in the War Effort we urge readers to request ONLY those bulletins which will be of value to them. Use the coupon on the facing page.

L-63 **Electronic Index of Industrial Equipment.** Bulletin 170, 8½" × 11", 4 pages. Electronic equipment for industrial applications and uses. Advances in electronic engineering have made possible such units as rectifiers for d-c. motors up to 200 H. P.; rectifiers for lifting magnets; variable voltage rectifiers having a range from 0 to 250 volts d.c.; the electronic controller to start, stop, accelerate, and regulate d-c. motor speeds with a high degree of accuracy; high-frequency inductors, static heating units, and low cycle converters which give 1800 VPM or less from a 60-cycle line. Electron Equipment Corp., Palm Springs, Calif.

L-64 **Temperature & Pressure Instruments.** Bulletin 102c, 3⅝" × 8½", 6 pages. Temperature and pressure regulators, pressure gauges, dial indicating thermometers, industrial and miscellaneous thermometers; temperature and pressure recorders and controllers; steam traps. H. O. Trerice Co., 1420 West Lafayette Blvd., Detroit 16, Mich.

L-65 **Signal System Cable and Wire Data.** Loose-leaf booklet, 4" × 6⅛", 24 pages three-hole punched. Valuable color code information in handy, quick-reference tables. Of interest to engineers, wiremen, or anyone else affiliated with signal systems. Tables include standard telephone cable color code (for 1—100 pairs incl.); interphone telephone and switchboard telephone cable data; copper wire resistance table; current carrying capacities of copper wire; and others. Cannon Electric Development Co., 3209 Humbolt St., Los Angeles, 31, Calif.

L-66 **Motorized Valves.** Catalog A-8½" × 11", 4-pages. A high speed mechanism to operate slip-stem valves for "On-Off" control of air, gas, oil, steam, water, etc. Small, medium, and large type mechanisms available in one to several speeds from 2 to 7 seconds per inch of valve stem travel. Lift force (push or pull on valve stem) from 80 to 550 pounds are developed. Catalog describes and illustrates available types by a suitable table or chart. Also provides a selection chart for ready reference, hook-up of system, valve data, specifications, etc. Automatic Temperature Control Company, Inc., 34 East Logan Street, Philadelphia, Pa.

L-67 **The C-D Capacitor.** November issue, 5½" × 7¾", 16-pages. Contains Part II of an interesting article "Super stability at UHF" with further discussion on coil factors which must be considered to attain a high degree of stability, high Q, and a minimum inductance vs. temperature change. The second article, "Wide Band Amplifiers" considers the design fundamentals of video amplifiers (television amplifiers). Text is technical in nature, and is adequately illustrated

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212 Fulton Street, New York 7, N. Y.

with diagrams and circuit drawings. Cornell Dubilier Electric Corp., 1049 Hamilton Blvd., So. Plainfield, N. J.

L-68 **Weight Adjusting.** Folder, 3⅜" × 8½", 4-pages. Detailed directions for adjusting and calibrating weights to within one-tenth milligram with weight adjusting apparatus. Thompson Balance Co., 808 20th Street, Denver, Colo.

L-69 **Pyrometers.** Catalog 1101 H, 8½" × 11", 38 pages. High speed photoelectrically balanced recorders, indicators, indicating controllers, and recording controllers. A beam of light reflected by a mirror-galvanometer to a photoelectric tube is used to control a motor driving the moving contact of a potentiometer or a bridge to maintain balance. Accuracy up to 0.1% is possible. Text fully explains principle of operation and is supplemented by numerous illustrations. C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn 5, N. Y.

L-70 **Automatic Temperature Control of Rotary Kilns.** Bulletin, 8¼" × 11½", 6 pages. Reprint of a paper describing the operation of automatic temperature control of a large rotary lime kiln. Faced with the problem of eliminating highly fluctuating temperatures encountered before application of automatic control, the author analyzes the problem and describes the method of controlling factors to obtain relative constant temperatures. Text is supplemented by diagrams and illustrations. Bristol Co., Waterbury 91, Conn.

L-71 **Adjustable Speed Simplicity from A. C. Lines.** Catalog Sheet 171, 8½" × 11", 2-pages. Features and advantages of electronic control of D. C. motors from A. C. lines. Electron Equipment Corp., Palm Springs, Calif.

L-72 **Thermometers.** Bulletin 20, 8½" × 11", 16 pages. Dimensions, specifications, and illustrations of straight and oblique shank thermometers for liquids; angle pattern thermometers for liquids; adjustable angle thermometers for air; and dial thermometers for liquids and air. Text explains the special features and advantages of each. Johnson Service Co., 507 E. Michigan St., Milwaukee 2, Wis.

L-73 **Magnetometer (aircraft analysis type).** Brochure, 8½" × 11", 12 pages. An electrical device which measures the direction and magnitude of the Earth's field at any given location. Instructions also explain how the instrument may be used to locate magnetic members in an aircraft and how to determine the subsequent influence on compass readings. Several other applications are also explained in brochure. Waugh Laboratories, Div. Waugh Equipment Co., 420 Lexington Ave., New York, N. Y.

L-74 **The Motorgram.** 8½" × 11", 4 pages. Contains helpful and interesting information for those readers concerned with fractional HP motors. Of particular interest is an article "Speed Control Characteristics of Fractional Horsepower Motors" wherein methods of controlling speeds are discussed, as well as advantages and disadvantages of each. Bodine Electric Co., 2250 W. Ohio St., Chicago 12, Ill.

L-75 **Special Purpose Capacitors.** Folder 721, 8½" × 11", 4 pages. Dimensions and specifications of special ceramic capacitors now in current production. This supplements bulletin No. 630 on ceramic capacitors and presents data not heretofore released in published form. Centralab, Division of Globe-Union Inv., 900 East Keefe Ave., Milwaukee, Wis.

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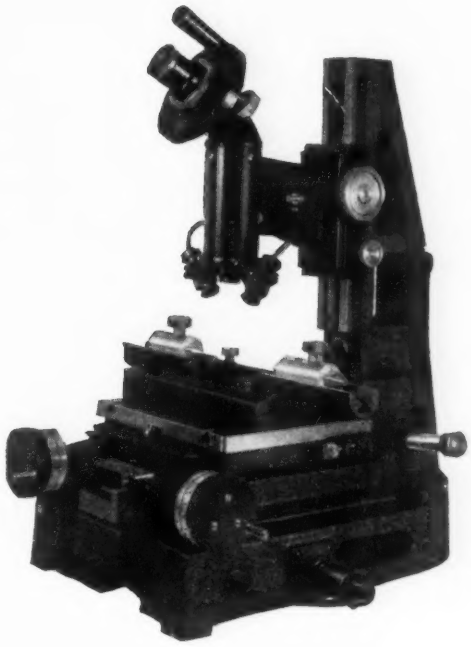

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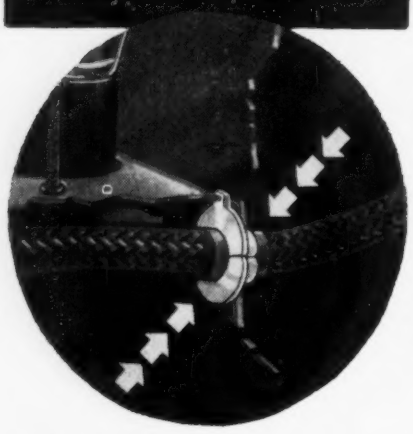

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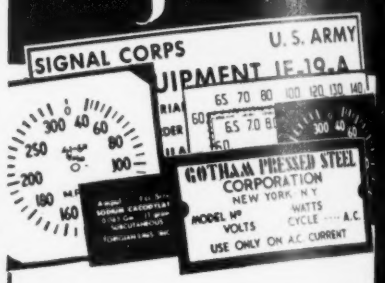

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